Prevalence and patterns of disease in early medieval populations : a comparison of skeletal samples from fifth to eighth century AD Britain and Southwestern Germany

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PREVALENCE AND PATTERNS OF DISEASE IN EARLY MEDIEVAL POPULATIONS:

A COMPARISON OF SKELETAL SAMPLES FROM FIFTH TO EIGHTH CENTURY AD BRITAIN AND SOUTHWESTERN GERMANY

by

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Volume 1 of 1

PhD Thesis
2004
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DECLARATION

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Abstract

This study analysed evidence for pathological changes seen on the skeletal remains of early medieval populations from two countries – Britain and Germany. A total of 928 individual skeletons dated between the mid-fifth and early eighth centuries AD were studied using macroscopic techniques. Two non-pathological indicators of health and disease – demographic structure and stature – were investigated in conjunction with six disease categories as diverse as dental disease, joint disease, traumatic injuries, non-specific infections, congenital and developmental anomalies, and metabolic disorders. To provide comparisons between the obtained results, Chi-squared tests were performed and the diseases in the study populations were discussed using a bioarchaeological approach.

Despite many similarities in disease prevalence, some striking differences between the two study populations were found. Most dental diseases, non-specific infections and iron-deficiency anaemia were more prevalent in German individuals. Some of these observations may be explained by differences in environmental factors which enhance the development of these diseases. Most noticeable was the relatively high percentage of cranial injuries found in German individuals, and especially in males attesting to a higher level of inter-personal violence.

TABLE OF CONTENTS

List of Maps

List of Tables

LIST OF FIGURES

LIST OF PLATES

Appendix C

ACKNOWLEDGEMENTS

This dissertation greatly benefited from the input, encouragement and profound knowledge of my PhD supervisor, Charlotte Roberts, for which I would like to thank her sincerely. I am also grateful to the people and institutions who provided access to the skeletal human remains curated by them; these are: Alfred Czarnetzki (Osteological Collection, Tübingen), Gary Green and Peter Rowe (Tees Archaeology), Kevin Leahy (North Lincolnshire Museum) and Liz Payce (Chichester Museum). In addition, Pia Nystrom and Andrew Chamberlain allowed the study of one of the skeletal samples (Castledyke South) using their workspace at the University of Sheffield. This is also the opportunity to thank Alfred Czarnetzki (Tübingen), Charlotte Roberts (Durham) and Herbert Ullrich (Berlin) for hooking me on the study of palaeopathology. I especially profited from unlimited access to the Osteological Collection at the University of Tübingen granted by Alfred Czarnetzki, who was always willing to discuss ideas on and diagnoses of pathological conditions.

My family provided me with their unconditional support, both financially as well as emotionally, and they never lost their keen interest in this dissertation project, for which I have to thank them. Christoph Jerusalem shared his knowledge of early medieval skeletons he had studied almost half a century ago while working at the Anatomical Institute in Tübingen.

It should not be forgotten that without the people who, although involuntarily, gave their bones to this study, the present project would not have been possible. Nor would it have been achievable without the work of the excavators and curators, who took care of the human bones.

On a lighter note but nevertheless equally appreciated was the friendship and help of past and present co-workers in Room 016 at the Department of Archaeology: Marie-Catherine Bernard, Anwen Caffell, Charlotte Henderson, Daniel Keller and Charlotte Whiting. Special thanks to Anwen Caffell for sharing information on preliminary results of her own PhD project. To Daniel Keller, who was always willing to go through lengthy discussions on human bones and pathological lesions, not only checked bibliographic references but was always there (or at least reachable by phone) when I needed him. I would also like to say thanks to Henrike Kiesewetter and Beate Ulmer for providing scientific knowledge, accommodation and numerous meals during my research in Tübingen. As always, although across the Atlantic, Liz Riorden cheered me up when things were not going too well.

Despite all the help and support I benefited from, writing meaningful sentences in a foreign language might produce astonishing and sometimes funny results. It also involved using the word 'however' a lot. The impact of my not always up to scratch knowledge of English grammar, spelling and punctuation on the readability of this dissertation has been greatly minimized by the scrutinising eye of Charlotte Roberts and the publication of 'Eats, Shoots & Leaves' by Lynn Truss (2003). However, all remaining mistakes are mine alone.

This dissertation has also been an exercise in finding a compromise between the format favoured at German universities, where doctoral theses in archaeological subjects are measured in kilos, and not by a word limit as implemented by the British university system. However, things might even change in Germany, since following the submission of a three-kilo PhD thesis, procedures to introduce a page limit on all doctoral dissertations are currently underway. Of course, this is no valid excuse for exceeding my word limit, although it has to be stressed that actually a large proportion of words and numbers are in the form of tables.

CHAPTER ONE

INTRODUCTION

1.1 AIMS OF THE STUDY

This dissertation attempts to study patterns of health and disease in two British and German skeletal populations. Both study samples were archaeologically dated to the mid-fifth to early eighth century AD, or the early medieval period. Each population was represented by three sub-samples which comprised a total of 928 individual skeletons – 433 from British and 495 from German cemetery samples. The following questions were posed:

- Which diseases were present in the study samples?
- Were there differences in prevalence rates between the two countries, between females and males, or children and adults?
- In cases where differences occurred, how can they be explained by using a biocultural approach to the data?

Hypothesizing that individuals living under similar conditions will show similar health and disease patterns, no significant differences between the early medieval populations studied here were expected. However, during data collection it already became obvious that some discrepancies between the study samples existed, with German individuals showing a wider array of diseases, as well as higher prevalence rates for some disease categories.

Since not all skeletal diseases seen in the study samples did allow a meaningful interpretation of their prevalence, either because only few cases were found or because their diagnosis was uncertain, not all pathological changes were evaluated in this dissertation. Ultimately, the following indicators of health and disease were used: demographic structure, adult stature and non-adult growth, dental disease, joint disease, trauma, non-specific infections, congenital and developmental anomalies and metabolic disorders.

1.2 CONCEPTS OF HEALTH AND DISEASE

Today a number of definitions of what is classified as 'disease' exist. For instance, in biomedical terms disease is seen as "a deviation from normal functioning, observable and measurable by biomedical tendencies in the examining room and laboratory" (McElroy and Townsend, 1996: 43). A much broader definition is given by the World Health Organization, declaring health a human right in 1978. Health is not only the opposite of disease; it is "a state of complete physical, mental, and social well-being, not merely the absence of disease or infirmity" (Garrett, 1994: 211). However, every person experiences disease individually, and societies may have different perceptions of what is seen as health or disease. Nevertheless, "one fact is certain, every human being, past and present, will have suffered from, or will succumb to, disease that will affect his or her normal daily life" (Roberts and Cox, 2003: 1). In a modern context, diseases are diagnosed by medically trained professionals and every attempt is made to treat the patient. Patterns of health and disease in the past can indicate how well populations have adapted to their environment and the study of these patterns is covered by the subject of palaeopathology, which is part of the study of biological anthropology or bioarchaeology, a term first coined by J. Buikstra, introducing it at a conference in 1976 (Larsen, 2000).

The term palaeopathology was first included in the American Standard Dictionary published in 1895 where it was defined in the following way: "The study of the evidence of injury and disease among ancient man and fossil animals is known as *Paleopathology*" (Moodie, 1923: 21). However, in 1914, Sir M. A. Ruffer (1859-1917) applied the same term to the methods he had developed through the study of Egyptian mummies' pathological anatomy (Spencer, 1997). As a science, palaeopathology has evolved from a descriptive early phase, in which diagnosis of pathological conditions becomes an end in itself (Spencer, 1997). However, palaeopathological studies were dominated by clinicians guarding what they perceived as their 'personal' hobby by claiming that only medically trained individuals would be able to "venture into the infinitely subtle field of ancient disease" (Wells, 1964: 20).

Since the later decades of the twentieth century, a move away from case studies of 'interesting' and 'unusual' skeletal pathologies has been made in Britain and population-based studies are now gaining ground. Nevertheless, it has been recognized that studies conducted in the United States preferentially include a biocultural approach when recording pathological skeletal changes (Roberts, 2002).

The 'biocultural approach' aims to link the biological evidence for disease with the cultural evidence of the people being studied. Human disease is determined by many factors, for example the sex and age of an individual, ethnicity, occupation, social status and population density, climate, levels of hygiene and diet (Roberts and Cox, 2003). Interestingly, some of these ideas are not as novel as one might think. Probably some of the earliest descriptions of sex differences in the susceptibility to disease and differences among social classes were voiced by Hippocrates in the fifth century BC. In his report on the 'Cough of Perinthus', a pneumonia epidemic which occurred in this Thracian town, he observed that women did not suffer as badly as men. He attributed this to the fact, that women were more housebound and, for most other diseases, women were not as badly affected as men. Furthermore, "only free-born women had anginas, which were benign to boot. Slave women were more severely affected, among whom there were some violent cases that soon proved fatal" (Grmek, 1989: 306).

1.3 STRUCTURE AND SIGNIFICANCE OF THE DISSERTATION

1.3.1 Structure of the dissertation

This dissertation attempts to provide insights into the disease patterns of contemporaneous skeletal populations from Britain and southwestern Germany. To achieve this a large number of human skeletal remains were analysed and interpreted, using a biocultural approach. By including information on the different backgrounds of archaeological, as well as anthropological research in the two countries, Chapter Two is meant as a short introduction to the study areas. Chapter Two also contains a historical summary of the chronological period to which the study populations belonged. Chapter Three provides information on the individual categories employed to assess health and disease patterns. Since the demographic structure and stature of a population are not strictly pathological parameters, although they can offer data that may indicate disease, they are included here, together with descriptions of pathological conditions diagnosed in the study samples. Again Chapter Four, is divided in two parts; the first provides archaeological information on each of the six cemeteries and some notes on how and where the individuals buried there were curated after excavation. A second part details the methods used to analyse the human skeletal remains. The results of this study are detailed in Chapter Five. Since it was necessary to include results for the number of individuals affected, as well as the number of bones observed, a large amount of data had to be put into text, tables and figures, making this chapter a number crunching experience. Chapter Six discusses the prevalence of specific diseases, as well as possible differences and similarities between the two study areas, and attempts to incorporate historical and archaeological data, in addition to other relevant skeletal studies. Chapter Seven summarizes these discussions and concludes with recommendations for future studies. All bibliographic references can be found in Chapter Eight. The Appendices contain: an example of the original recording format, which was used to gather information on each skeletal (Appendix A), and a database with preservation scores for each individual on CD-ROM (Appendix B). Appendix C is partially accessible on CD-ROM, since demographic information for all 928 individuals would have taken up too much space when committed to paper. Post-cranial measurements taken to calculate adult stature are equally confined to CD-ROM. However, detailed descriptions of individual cases of disease can be found in a printed format in Appendix C. The exceptions are all dental diseases and spinal osteoarthritis, since a large number of individuals displayed evidence for one or both.

1.3.2 Significance of the dissertation

Over the years, population-based studies of skeletal human remains have become more numerous in English publications. However, this cannot be said about German research on the population health of archaeological human material. Although numerous studies of skeletons from all time periods are available, comprehensive data presentation on disease frequencies is usually absent from most of these studies. Since there are problems with the comparability of data on palaeopathological conditions derived from different researchers, this dissertation projects provides results based on a large number of individuals, all analysed by the same researcher, consistently using the same methods to record and diagnose pathological conditions, thus providing a unique record of the variety of diseases present in Britain and Germany during the early medieval period, spanning from the mid-fifth to the early eighth century AD.

1.4 DEFINITIONS

Certain clarifications should be made in order to avoid confusion about specific terms used throughout this study. Firstly, individuals and populations from the study samples will be referred to as 'British' and 'German', according to the country the individual or sample derived from. This is not meant to imply ethnicity in terms of their biological affinity, but these terms are used rather to denote modern political boundaries. Alternatively, 'Anglo-Saxon' and 'Alamanni' would have been available to differentiate individuals from the two countries. As both terms bear an ethnic connotation, it was decided not to use them.

Secondly, the terms 'non-adult', subadult and 'child/children' are given to all individuals under the age of 16 years. However, 'infant' describes an individual who died before reaching the end of his or her first year. Lastly, 'female', 'male', 'woman/women' and 'man/men' are used solely to describe biological sex as inferred from morphological skeletal traits, and not gender, which is based on social classifications and does not necessarily equate to biological sex.

Finally, 'population' or 'sample' denotes a group of individuals likely to be buried in the same cemetery. In the biological sense of these terms, they also stand for a number of individuals with a high likelihood of mating.

The following chapter sets out to provide a short background to archaeological studies of the early medieval period in Britain and Germany. Additionally, problems with the incorporation of bioarchaeological data by archaeologists are outlined. Differences in the focus of osteological studies in the two countries are mentioned, as well as the consequences of different research paradigms for the present study.

CHAPTER TWO

BACKGROUND TO EARLY MEDIEVAL ARCHAEOLOGY AND PALAEOPATHOLOGICAL RESEARCH IN BRITAIN AND GERMANY

2.1 BACKGROUND TO EARLY MEDIEVAL ARCHAEOLOGY IN BRITAIN AND GERMANY

Two different myths on the origin of British people have been described by Lucy (1998): the Trojan and the Germanic ancestors. The first, widely believed until the sixteenth century, traced the origin of the British people through Japhet, Brutus and Arthur back to the fall of Troy. This story was given up in favour of a Germanic ancestry, also described as Anglo-Saxonism, assuming that large numbers of northern Germanic tribes invaded Britain and eventually settled here. This was eloquently proved by textual evidence provided by Bede, Gildas and the scribes of the Anglo-Saxon Chronicle, in which numerous attacks by shiploads of Germanic warriors commanded by leaders, such as Hengist and Horsa, were detailed. Furthermore, the Anglo-Saxon Chronicles, designed as annals, listed memorable events that occurred since the Romans had left Britain. Information on the names of kings, their successors and predecessors, whom they killed and which battles they fought were provided (Swanton, 2000). For example, "in 488 AD, Ælle and Cissa besieged Anderitum, and killed all who lived in there; there was not even one Britain left there" (Swanton, 2000: 14) and further, in 597 AD "Ceolwulf began to rule in Wessex, and he continually fought and strove either against the Angle race, or against the Welsh, or against the Picts, or against the Scots" (Swanton, 2000: 21).

Until the mid-nineteenth century, archaeology in Britain had not evolved as an independent discipline, remaining secondary to history, and Anglo-Saxonism was used in political and religious debates to prove continuity of these institutions. At the end of the eighteenth century, a growing nationalistic perspective led scholars to argue that the formerly indigenous population had been enslaved, destroyed or displaced by the Germanic invaders, thus implying a Germanic origin of the present people. This reasoning was largely based on historical, not archaeological evidence. However, the increasing number of archaeological finds due to the development of the railway system and enlarging towns resulted in a growing number of archaeological societies, founded by members of the middle classes. They tried to attribute artefacts to one of the three Germanic tribes mentioned by Bede (McClure and Collins, 1999). This creation of ethnic boundaries was more firmly established after G. Kossinna (1911) had published his thoughts on settlement archaeology, claiming that sharply defined archaeological culture areas coincide with settlement areas of specific peoples. Until the 1940s, few settlements dated to the early medieval period had been excavated and the vast majority of finds derived from cemetery excavations (Webster, 1986). However, these finds lent themselves to typological arrangement. Chronological systems were devised, relying on typological developments, and well into the twentieth century grave finds remained the major form of early medieval object studied (Lucy, 2002).

Likely to be a result of anti-German sentiments in the 1930s, a re-thinking of the supposed extermination of the original British population took place (e.g., Leeds, 1936). In the second half of the twentieth century, the view that many of the original peoples had survived was strengthened by the development of new archaeological methods, such as pollen analysis and scientific dating techniques, in combination with settlement excavations. Over recent years, many researchers have started to look at the wider meaning of objects included in graves and not at the objects in terms of 'wealth' and 'ethnicity' (e.g., Pader, 1982; Lucy, 1998; O'Brien, 1999). However, even today little detailed knowledge on specific aspects of early medieval people in Britain has been gathered. For instance, Blair (2003: 257) concluded that:

> "The people of Anglo-Saxon England were mainly an agricultural people who lived in villages, farms and hamlets. With few exceptions, towns did not play an important part in the life of the country until the tenth century. So much may be said with confidence, but beyond this, and despite all that has been written about it, the agrarian organization of the Anglo-Saxon community remains a topic full of hazards, controversies and uncertainties."

In southwest Germany, the earliest recorded finds of what was then termed 'heathen's graves' were made at the end of the sixteenth century and continued until the nineteenth century as an uncontrolled search for treasures, resulting in the looting of numerous graves (Fingerlin, 1998). This practice was certainly not restricted to burials of the early medieval period, but their large number and conspicuous alignment in rows must have made their detection easy. Influenced by the Romantic movement of the nineteenth century, archaeology was very much concentrated on researching classical Greek and Roman antiquities and far less interest was taken in finds from their own country. Only in the wake of the newly expanding railway system, many row grave cemeteries were discovered and this led to the foundation of historical and archaeological societies throughout southern Germany, a development similar to that seen in Britain. Despite this growing interest in local archaeology, the lack of proper recording and retaining of human skeletal remains resulted in the loss of probably thousands of skeletons. It is not quite clear from what point these graves and their inhabitants were identified as Alamanni but, by 1846, the excavator of the row grave cemetery near Oberflacht used this term (von Dürrich and Menzel, 1847). Oberflacht was exceptional due to its preservation of wood, textiles and leather in the waterlogged ground (Paulsen, 1992; Schiek, 1992). However, while most of these finds have been recently re-published, the human bones were not curated. Parallel to the ethnic name of Alamanni, the time period was also referred to as Merovingian, named after the Frankish dynasty. The growing number of artefacts resulted in a compilation of all known finds by L. Lindenschmit (1880-1889). Typological studies allowed the creation of relative chronologies, and finds could also be dated absolutely through coins included in a number of graves. However, in the following century, each excavator devised his or her own chronological system, which resulted in a confusing number of independent relative chronologies (Christlein, 1979). Apart from chronological questions, the main research emphasis concentrated on the correlation of grave-goods with social status and/or the ethnicity of the person they were found with (Christlein, 1973). Despite the large number of excavated cemeteries and few settlement sites dated to the early medieval period, little is historically known about the people who had created these objects.

By the late third and early fourth century AD, a Germanic tribe known as 'Alamanni' or 'Alemanni' ('all men') occupied what later became southwestern Germany and northern Switzerland. According to the Roman chronicler Asinius Quadratus (third century AD), cited by the sixth-century AD Byzantine historian Agathius, the Alamanni were "a motley crowd" (Dirlmeier and Gottlieb, 1978: 80). They originated from peoples living in central Germany in the River Elbe and Havel region, from where they moved southwards in the second century AD. The first time the Alamanni were mentioned in Roman records was in the second half of the third century AD, as part of other German tribes coming in conflict with the Roman army (Schach-Dörges, 1998). Despite the animosities between Romans and Germanic tribes, many Alemannic mercenaries, or former prisoners of war, fought in the Roman army against their own people and some held high ranks as troop commanders and tribunes (Martin, 1998). One, the Alamanni *rex* Chrocus, led his army to Britain to support the Roman occupation forces in the early fourth century AD (Hartung, 1983).

After continued attacks by Germanic troops, the Roman army finally had to abandon the upper Germanic and Raetian *Limes*, retreating west and south of the River Rhine in the second half of the third century AD, leaving already settled land for the Alamanni to occupy. The existing Romanised population was likely to have been integrated into the Alamannic federation, although this is a fairly recent view (Schutz, 2000). During the fourth century, hostility between Alamannic and Roman soldiers frequently flared up on the borders of what was then known as Alamannia. Many of these battles severely reduced the number of Alamanni warriors, if the number reported by Roman historians are to be believed. During a battle near Straßburg in 377 AD, 40,000 Alamannic warriors lost their life (Dirlmeier and Gottlieb, 1978). Even if these numbers are exaggerated, a steady influx of people from the north might have helped to settle more land (Schutz, 2000). Over the next two-hundred year period, Alamannic influence and territory expanded in all directions, leading to conflicts with the Franks who had built a vast empire, originating in northern Gaul (Geuenich, 1998). Under the Merovingian kings, named after their founder Merovech, Frankish troops engaged in battle with their neighbours to the east. In 496 AD, the Alemanni were beaten into submission near Tolbiacum (the modern town of Zülpich in Nordrhine-Westphalia) by superior Frankish forces or, as reported by Gregory of Tours, due to the Frankish king Clovis being converted to Christianity (Thorpe, 1974). Subsequently all their territory north of the modern town of Ludwigsburg (near Stuttgart) was lost to Frankish influence. The Alamannic uprising against Frankish rule in 506 AD was equally quenched. Nevertheless, few changes in everyday life would have been noticeable to the inhabitants of Alamannia. As far as they had survived the battles with the Franks, the Alamannic ruling class was still in power, but now answering to the Frankish call to arms.

It is difficult to evaluate the history of the Alemannic people as no records written by them exist. Apart from the two law codices – *Pactus* and *Lex Alamannorum* – and a few runic inscriptions on objects to denote their ownership, all historical events concerning the Alamanni were written by others, such as Roman, Frankish or Byzantine authors (Dirlmeier and Gottlieb, 1976; 1978). Furthermore, these accounts give no information on the vast majority of the Alamannic people who ranked below the elite, and even modern scholars only discuss the organization and powers of the nobility; the early medieval peasant remains unaccounted for, in both the historical and the modern literature. Being left with this heavily biased picture compiled by outsiders, it might be concluded that the Alamanni consisted not of a homogenous group of people, but rather of a group of people from different origins having the same settlement area in common. However, parallel to Reynolds' (1985: 414) cautions that "we might do well to remember that the early medieval English did not call themselves Anglo-Saxons," it can be assumed that the early medieval people living in southwestern Germany did not call themselves Alamanni.

2.2 Background to palaeopathological research in Britain and Germany

The handbook by G. Fehring (1991) which provides an introduction to medieval German archaeology, spends one short paragraph on the importance of anthropological research in relation to medieval archaeology. Fehring (1991: 65) states that, "It is possible to work out sex, age, height, and illnesses from a skeleton." He also informs his readers about the main aims of anthropological studies: demography, morphology and pathology. Of most crucial importance, in his opinion, is the correlation of anthropological observations and grave-goods which allows for an analysis of social organisation. Furthermore, apparently higher status males, identified by their swords, had longer and narrower skulls, which "clearly reflects social status, achieved through birth and/or way of life" (Fehring, 1991: 66). These statements provide an insight into commonly held beliefs about what biological anthropology should be concerned with from an archaeologist's point of view. A similar view of biological anthropology as a complementary science to archaeology has also been voiced by Eggers (1986).

In some instances, the merits of osteological analyses have been recognized and can be found in German-speaking publications. For example, G. Asmus (1962: 193) remarked that "physical anthropology, when applied in a correct manner, holds a key position and can answer questions which could not be solved by simply using an archaeological approach." Regrettably, this view was not shared by everybody and, even in recent publications, astounding misconceptions as to what extent bioarchaeological information should be included have been voiced by archaeologists. The publication of the Pleidelsheim cemetery in southwestern Germany by U. Koch (2001) included only basic biological information for each skeleton (age and sex), confined to the grave catalogue, dedicating the volume to lists of grave-goods and comparative finds, as well as to more general historical research into the early medieval period. In other cases, where anthropological data was included in cemetery analyses, interesting conclusions have been reached. For instance, Irlinger and Wernard (1999) inferred from their observations of thin cortical bone, a mainly edentulous jaw and 'sabre-like' thigh bones as that the skeleton was that of an old woman. However, the possibility of pathological changes having led to their observations was not considered. A final example should suffice to demonstrate how *ad hoc* assumptions on pathological changes without real considerations of differential diagnoses can be misleading. Kunter (1987) concluded that the greater than normal angulation of the femoral neck, which he observed in a male individual dated to the early medieval period, was unlikely to have been caused by a congenital condition (he does not say which one). He further reasoned that it was in all probability due to rickets because, additionally, the individual had three teeth with hypoplastic defects, indicative of childhood rickets!

Apart from these problems with diagnostic criteria and the lack of descriptions of the observed lesions, there are also difficulties with the comparison of osteological data between British and German publications. Many dental pathology analyses by German-speaking researchers present caries prevalence in two different ways: caries intensity (*Kariesintensität*) and caries frequency (*Kariesfrequenz*) (e.g., Abels *et al.*, 1972; Queisser, 1988). Although comparable expressions are used by British and American bioarchaeologists, they have a different meaning. Caries 'intensity' in the German sense of the word is defined as the percentage of teeth with caries in relation to the number of observable teeth plus the percentage of teeth lost ante-mortem in relation to tooth sockets observable. Caries 'frequency' refers to the percentage of teeth with caries, plus the percentage of individuals with at least one carious tooth, plus the percentage of individuals with at least one tooth lost ante-mortem (Queisser, 1988). In contrast, 'caries frequency' used by a British bioarchaeologist indicates the percentage of carious teeth in relation to the number of teeth observable.

Interestingly, comparatively little emphasis is given to palaeopathology in German anthropological studies and this might explain the lack of a theoretical background, as well as a consensus on diagnosis. The recent publication of an early medieval cemetery in Austria may be used as an example (Fabrizii-Reuer and Reuer, 2001). The volume is clearly intended as an anthropological evaluation of the human skeletal remains as the title suggests. Demography, metrical data of the skull and post-cranial skeleton, anatomical variants, as well as intra- and interserial analyses are discussed in great length. However, pathological conditions are dealt with very briefly and, of the more than one hundred pages of text, only eighteen refer to pathological changes, robusticity and stature. This emphasis on metrical data is reflected in earlier German studies. For example, Rösing and Schwidetzky (1979) based their comparative statistical analysis of early medieval populations on ten measurements of 7,878 male individuals.

In contrast, many more reports on pathological conditions are available for early medieval British cemeteries, although not all of them have been published. However, Roberts and Cox (2003) included 72 palaeopathological skeletal reports approximately spanning the fifth to tenth century AD in their recent survey on health and disease in Britain. The question why there is such an obvious discrepancy between the focus of palaeopathological analyses in Britain and Germany has to be asked. In both countries, human skeletal remains from the early medieval period outnumber the skeletal evidence from other periods, with the exception of late medieval and post-medieval times. An estimated 15,000 skeletons have been excavated in southwestern Germany alone (Wahl *et al.*, 1998) and for Britain, 7,122 individuals have been reported, although this is an under-estimate of the true number of individuals from this time period (Roberts and Cox, 2003). Therefore, a lack of skeletal samples cannot be responsible. However, although this cannot be expressed in numbers, more British bioarchaeologists seem to focus on the subject of palaeopathology, compared to German researchers. It is suspected that this discrepancy has its origin in the different university structures of the two countries. Roberts (2002) summarized data on university courses which provide teaching in biological anthropology and found that only ten archaeology departments actually include biological anthropology (and palaeopathology) in their curriculum. However, many of these courses are taught on a postgraduate level and offer thorough and intense training, with additional specialization in palaeopathology. In Germany, biological anthropology can be studied within the subject of human biology with a clear focus on genetic studies. There are currently twelve German-speaking universities (including Vienna and Zürich), where anthropology can be studied, although some offer only a maximum of four hours of teaching per week (Grupe, 2002). Furthermore, at a few universities, biological anthropology can be studied as a minor subject, in conjunction with archaeological studies; again some offer a maximum of four hours per week, covering aspects such as human evolution, osteology, osteometry and palaeopathology. There is obviously a genuine dearth of these teaching facilities in Germany. However, as universities have to rely entirely on funding provided by the individual states, there appears to be no solution to this problem.

Despite a different approach to the study of human skeletal remains in Britain and Germany, when it comes to the co-operation between archaeology and physical anthropology, a similar tendency is obvious. This becomes apparent when attitudes of archaeologists towards biological sex determination are reviewed. In both countries, biological sex assignments are never favoured over gender based on grave-goods when disagreement between the two arises. This position is grounded on two unverified assumptions: firstly, that biological sex equals gender and, secondly, that gender is reflected in the grave-goods a person is buried with. Archaeologists argue that scientific results may be faulty due to fragmentary human remains and in this case prefer their 'archaeological' sex determination based on grave-goods (e.g., Evison, 1987; Knaut, 1993). However, rejecting results that do not confirm the stereotype, but accepting the ones that do, cannot be accepted. Knaut (1993: 429) proposed "to use a combination of both methods to minimize the number of burials of undetermined sex." Thus, sex and gender are merged into one category, assuming that a person was either female or male, and was buried with the appropriate grave-goods to reflect one of these categories. This attitude also assumes a bi-polarity of sex (female/male) and gender (feminine/masculine), ignoring the possibility of other variations (Stoodley, 1999). Examples of this stereotypical way of thinking resulted in the picture of Germanic warriors bristling with weapons and constantly at war with their neighbours, and their daughters and wives waiting at home and receiving more items of jewellery after each successful raid. Since women would eventually be buried with these items, the grave-goods should reflect the status of their father and husband (Arnold, 1984). However, this picture rather reflects antiquarian ideas about sex and gender originating in the mid-nineteenth century (Lucy, 1998).

This chapter has demonstrated similar beginnings in the study of early medieval cemeteries in Britain and Germany. Nevertheless, while research in Britain has evolved further away from studying excavated grave-goods for typological reasons, German archaeologists still entertain the same approach as their antiquarian predecessors in their typological assessment of grave finds. It is also noticeable that, originally, both felt that early medieval populations were seen as invaders who exterminated the indigenous population. However, in British archaeology this notion has been largely replaced, and the German archaeologist either ignores the presence of an original population or sees them as being enslaved by invading Germanic tribes, although this attitude might be about to change. Contrary to British reports on human skeletal remains, there have been only few studies of palaeopathology in the early medieval period of Germany, although osteometric and demographic analyses exist in relative abundance. Furthermore, population-based skeletal studies of pathological conditions are virtually absent for

German skeletal human remains. This discrepancy may be due to differences in teaching the subject at British and German universities, where in the latter metrical analyses of biological features are favoured over the study of pathological conditions.

In Chapter Three, each of the parameters chosen to assess health and disease in the study populations will be described, providing background information on earlier studies of specific indicators, as well as problems in their interpretation.

Chapter Three

Background to Indicators of Health and Disease

3.1 Demography

Archaeologists, anthropologists and historians alike all depend on mortality profiles derived from prehistoric and historic cemetery populations. This demographic information is used to assess life expectancy, fertility and population size, in addition to health and disease patterns (Ubelaker, 2001). Regrettably, the accuracy of osteologically derived information on age, and to a lesser extent on sex needs to be examined, since there lies the most crucial source of error. At best "the attribution of biological profiles merely represents a well-founded estimate" in adult individuals (Kemkes-Grottenthaler, 2002: 48). Rather than representing an estimate of the biological age of a person instead of their chronological age, changes observed in different skeletal elements are correlated with ageing. The pace of ageing itself is dependant on several factors such as sex, genetics, pathologies and the interaction with the environment and there is no reliable indication that these processes occur at a constant rate throughout an individual's adult life. Furthermore, 'risk-factors' in palaeodemographic studies of archaeological human remains entail inter- and intra-observer error, asymmetry of bilateral traits and the correlation between several traits in the same individual.

Methods used in age assessment are more precise in younger individuals than in older people, since the development of the teeth and bones during the growth period up to the age of around 25 years proceeds in a fairly predictable way. However, after the third decade of life, the main means of estimating the length of a person's life in skeletal material is through a study of the degeneration of certain landmarks on the skull and pelvis, e.g., the degeneration of the auricular surface of the ilium. The rate of such changes varies considerably not only between individuals but also within individual regions of the same person, and categorization into broad age groups is the best result that can be achieved.

Today, bioarchaeologists have the opportunity to chose from a multitude of ageing techniques, which can be classified generally into macroscopic, microscopic and histological methods, all with their own advantages and disadvantages (Jackes, 1992). Despite this choice many studies of archaeological human remains focus on macroscopic ageing techniques, because they are usually less time consuming, cheaper and non-destructive. This is especially important when data for population-based studies is collected, where large numbers of skeletons need to be recorded.

Methodological problems of macroscopic age determination derive from the reference sample used to develop individual ageing methods. Obviously, to obtain testable results, only osteological collections of known-age and sex can be used. The inherent problem identified in the use of skeletal populations was first addressed by the French demographers Bocquet-Appel and Massett (1982) who demonstrated that the estimated age structure of any archaeological population (the target population) would reflect the age structure of the reference sample on which the ageing method was based and, hence, announced the much debated death of palaeodemography *per se* (Bocquet-Appel, 1986; Bocquet-Appel and Massett, 1985; 1996). However, this has been denied by many researchers (e.g., Van Gerven and Armelagos, 1983; Buikstra and Konigsberg, 1985; Greene *et al.*, 1986).

The most logical solution to the age structure problem of reference samples would be to use collections with an even age distribution. However, as the number of known-age and sex collections is limited, the use of statistical methods to exclude the effects of sample-specific age structures might be more effective (Akroyd *et al.*, 1999; Chamberlain, 2000). Although the degree of accuracy may be improved that way, there are no means to measure how accurate adult age estimation of archaeological human remains really is. Development, testing and calibration of ageing techniques on modern populations does not guarantee accuracy when applied to past populations, whose life style and environment may have unknown impacts on degenerative skeletal changes used in age estimations.

The most commonly used human skeletal collections are the Terry Collection (National Museum of Natural History/Smithsonian Institution, Washington, DC) and the Hamann-Todd Collection (Museum of Natural History, Cleveland, Ohio); both were widely employed in the development and testing of ageing methods. However, there are intrinsic problems with both of these reference collections, which are conveniently ignored by most researchers. A large number of individuals in the Terry Collection was aged by self-reported data and not by vital records. Age inconsistencies, either because real age was unknown or misrepresented, may have led to a high factor of uncertainty about the real age structure of this collection. Furthermore, both reference collections contain only a subset of individuals and are therefore biased according to their sample strategies (Usher, 2002). They included unclaimed or indigent bodies as well as bodies willed to be used for research. However, a study by Ericksen (1982) revealed that the differences in the Terry Collection were not noticeable enough to hinder age estimation, although only one skeletal element was used to obtain this result. Nevertheless, the Terry Collection is heavily biased in other ways, since it consists mainly of people living in St. Louis, Missouri during the first half of the twentieth century and it contains few women, but many males of Caucasian and Afro-American origins and people from a low socio-economic background.

3.2 STATURE ESTIMATION

Since the human skeleton is responding to environmental factors during the earlier periods of life, the calculation of body height or stature enables us to draw conclusions about the general health of a population (Nickens, 1976). Environmental factors such as climate and altitude can influence body height (Frisancho and Baker, 1970; Panter-Brick, 1997). Other contributing aspects include nutrition and certain diseases, such as chronic infections (Ulijaszek, 1990). Socio-economic status in the form of preferential access to a high quality diet can also lead to height increase. In contrast, a low socio-economic status might restrict the availability of certain essential food groups, such as proteins (Stinson, 1985). Nevertheless, stature remains influenced by the genetic makeup of a population, although the exact percentage to which genetics play a role in contrast to environmental factors is yet undetermined (Hanson, 1992; Bogin, 1999).

Height calculations are one of the standard features, next to age and sex assessment, included in almost all skeletal reports. Little interpretation of these results is usually undertaken beyond the point of comparing female and male adult mean height, perhaps mentioning height ranges and, sometimes, comparing these findings with other populations from a corresponding time period and/or geographical area, concluding that the population studied was similar, shorter or taller to the ones it was compared to (e.g., Creel, 1966: 91; Czarnetzki *et al.*, 1983; Hahn, 1993: Fig. 343).

Stature is a polygenetic trait, implying that it is influenced by more than one gene (Bogin, 1999) and this provides every individual with the potential to achieve his or her full adult height. Growth hormones secreted from the pituitary gland control the growth process, which in long bones takes place at the metaphyses, the area between the diaphysis and the epiphysis, commencing when the latter is fused (e.g., Swoboda, 1969; Karlsberg, 1998). Therefore, the lack or reduced secretion of growth hormones will lead to smaller than normal individuals. Growth hormones, such as insulin-like growth factor-1 are influenced by the nutritional state of the individual (Roche and Sun, 2003). However, modern data suggests that growth hormone deficiency is relatively rare; it is estimated to occur in between 1:4,000 to 1:10,000 live births (Mullis *et al.*, 2002).

Two commonly used ways of assessing growth exist for modern researchers; firstly, one can evaluate the amount of growth achieved at a specific time, and secondly, the rate of growth over time (velocity) can be assessed. Velocity curves reveal the rate at which a child is growing. However, the latter method is not applicable to human skeletal remains, because of the cross-sectional nature of samples, making it impossible to measure the growth rate of individuals over a time period (Goode *et al.*, 1993). Growth itself can be divided into four separate periods: prenatal, birth-adolescence, adolescence and adult (Tanner, 1953). Environmental factors influence growth differently at any of these periods (Tanner, 1981). The growth of the embryo is genetically determined, with growth slowing down gradually by the end of the gestation period (Snow, 1986). During the first three months *in utero,* the embryo is highly susceptible to genetic mutations and the influence of damaging environmental agents introduced via the mother. Maternal malnutrition and the size of the newborn baby are thought to be linked (Tanner, 1953), while others assume a buffering process which protects the foetus from nutritional stress (Stini, 1985). The size of the uterus is equally important for the size of the foetus, with small uteri restricting the growth of the embryo more than a large one (Snow, 1989). Growth velocity during infancy is rapid and any unfavourable factors can have a significant effect on adult stature (Saunders and Hoppa, 1993; Saunders *et al.*, 1993a). Differences in growth during childhood and adolescence result in different heights for males and females in adulthood. Adolescence is reached earlier by girls than by boys and, consequently, lacking several years of growth, females are usually smaller (Tanner, 1978). Malnourished individuals or people suffering from chronic disease may continue to grow until their mid-twenties, while healthy females reach their final height by the age of 18 and males by 21 years (Bogin, 1999). This demonstrates the individual's potential of adapting to environmental stress, especially during childhood and adolescence (Schell, 1995). In particular, the correlation between small height and low energy intake was noted (Ulijaszek, 1995). However, growth and height reflect a much more multifaceted interaction between the environment and genetics and ultimately, "the extent to which timing, duration, and severity of inadequate nourishment during infancy, childhood and adolescence may lead to compromised adult stature is largely unknown" (Largo, 1999: 164).

Numerous – often linked – environmental aspects can either promote or hinder growth. Mal- or undernourished children are more prone to infection (Garrow and James, 1993). Children suffering from chronic disease are more likely to experience undernourishment than their healthy peers. Children from low socio-economic families tend to display poorer nutrition and healthcare, again, leaving these children more prone to certain chronic diseases. Urban and rural environments play their different roles in an individual's health status, with rural populations supposedly having better access to fresh and, therefore, healthier food, unless food stuffs have to be sold to urban centres. Crowded living conditions in towns and cities have a contrary effect on health, with a large numbers of potential hosts playing their part in the transmission of infectious diseases. However, contrary to rural settlements, health care and sanitation facilities may be more available in cities (Bogin, 1988).

Socio-economic status and living conditions are intimately linked to nutrition which provided the energy needed for growth and well-being. While undernutrition may be defined as being caused by inadequate food quality with not enough available calories, malnutrition is linked to the inadequacy of certain essential dietary elements such as proteins, minerals or vitamins (Garrow and James, 1993). Preferential feeding of higher-quality foods to boys may lead to both undernutrition and malnourishment in girls even in societies not experiencing food scarcities (Messer, 1989). Especially during the first three years of life following birth, undernutrition can have severe consequences for the achievement of final adult stature. Most children are being weaned at some time during this period with the risk of undernourishment or malnourishment, as well as the introduction of new pathogens through supplementary food. At this point in time, children's immune systems are no longer protected by breast-feeding and the rapidly occurring growth makes them more susceptible to environmental stress (Saunders and Hoppa, 1993).

The concept of catch-up growth has been defined as the acceleration in growth "seen in many children during recovery from serious illnesses or from environments that retard growth" (Roche and Sun, 2003: 108). Catch-up growth will only commence when adequate nutrition becomes available and much of the potential height may actually be reached by an increase in growth velocity. Permanent dietary deficiency will ultimately lead to stunted growth, although a prolonged growth period into adulthood may enable the individual to compensate for at least some of it. Next to the early childhood years, adolescence poses similar threats of stunted growth due to dietary deficiencies because more calories are required during these last growth spurts (Eveleth and Tanner, 1990). Again, an extended growth period may compensate for this.

Disease can prevent the attainment of ultimate adult height or in children reaching their optimal height-at-age. For the period of illness more energy may be necessary to fight the disease, although the actual amount of food intake normally decreases, leading to subsequent malnutrition, which again, makes the individual more susceptible to disease (Scrimshaw *et al.*, 1959). Children at the weaning age are especially prone to 'weanling diarrhoea'. Without the protection of maternal anti-bodies, the child is exposed to external pathogen loads and environmental stressors. This stage in life is made responsible for the high number of childhood deaths in present and past societies (Gordon *et al.*, 1963). Considering all these factors, a cautionary note has to be added to the assumption that 'small equals health compromised'. Pelto and Pelto (1989) have argued that short individuals are actually healthy and well adapted to dietary deficiencies. While growing children adjust their growth rate to the availability of food, as adults these individuals would require less calorie intake to maintain their body functions.

Adult stature provides information about the general level of stress – environmental or disease-introduced – which a population experienced, while the comparison of subadult height-at-age may give more detailed answers to when stress occurred, especially when combined with certain stress indicators such as cribra orbitalia and enamel hypoplasia (Ribot and Roberts, 1996). However, limitations of studying stature and comparing results within and between skeletal samples are numerous. Subadult skeletons are generally less well preserved than adult remains and their bones may be under-represented due to less careful excavation methods. Differential burial practices – i.e. separate burial places within a cemetery not fully excavated, or burial completely separated from the actual cemetery – may prevent them from being visible in the archaeological record.

The estimation of stature in the living and the dead has a long history. Tanner (1998) mentioned the first known record of a growth study, although probably not for scientific analysis, when the height of the son of an eighteenth-century nobleman was measured every six months between birth until he reached the age of eighteen. During the last 150 years, several different methods have been developed in order to estimate the living height of skeletal human remains. A plethora of different formulae exists for calculating height of adult individuals from different ethnic groups, since different populations may have different limb proportions (Hanson, 1992). For German males, Breitinger (1937) developed regression formulae based on measurements taken from 2,400 athletes attending a gymnastic festival in 1923. Only considerably later, comparable regression formulae for German females were published by Bach (1965). However, there are several problems with these two approaches, although sometimes Bach and Breitinger's formulae are still preferred over Trotter and Gleser's formulae (e.g., Glowatzki, 1971; Abels *et al.*, 1972; Bay-Schuller, 1976; Hahn, 1993; Hollack and Kunter, 2001). Although based on a large number of individuals, Breitinger (1937) included only athletes in his male sample, and being young athletic men they were probably not representative of the entire population. Krogman and İşcan (1986) noticed that Breitinger's formulae produced consistently higher stature estimates when compared with results achieved by other methods. Furthermore, the female regression formulae by Bach (1965) were established on a small sample (n=400) of female students attending the University of Jena and an even smaller sample (n=100) of non-students from the same city; the sample is hardly representative of the entire population. Additionally, the lowest standard deviation was more than 4 cm (almost 2 inches) for both sexes, using femoral diaphyseal length.

Trotter and Gleser (1952) developed their formulae for American whites and Americans of African origin using data from the Terry Collection and military personnel serving in the Second World War. Their formulae were re-evaluated, employing measurements taken on Korean War deads (Trotter and Gleser, 1958), with further minor corrections (Trotter and Gleser, 1977). However, although their regression formulae were based on modern populations of probably different ethnic origins than archaeological samples, and therefore, not strictly applicable to past populations, they are still the most commonly used in bioarchaeology (Krogman and İşcan, 1986). Nevertheless, in recent years questions have been asked concerning the reliability of some measurements originally undertaken by Trotter and Gleser (Jantz, 1992; Jantz *et al.*, 1994). Obvious discrepancies have been noticed when diaphyseal length of the tibia was measured and this might have introduced some error into regression formulae based on tibial diaphyseal length.

One of the earlier studies of stature including English skeletal remains was restricted to male individuals dating from the Neolithic to the medieval period (L. W. Wells, 1963). An increase from the relatively short Iron Age stature was noted for the Anglo-Saxon period followed by another decline in height in later medieval times. Roberts and

Manchester (1995) gave a more detailed overview containing collated Anglo-Saxon female and male stature from several sites, strengthening Wells' findings.

The increase in Anglo-Saxon stature compared to the relatively short Iron Age populations in Britain may be attributed to a reduced pathogen load leading to a general increase in health, an increased nutritional status, or the arrival of Germanic tribes contributing their genetic potential of elevated height to the Anglo-Saxon gene pool (Roberts and Cox, 2003). Roman authors mention the physical appearance of their barbaric opponents during the numerous battles and skirmishes – the Germanic peoples are usually described as tall and fierce looking (Fuhrmann, 1971) – this description may well have been for propaganda purposes and, therefore, far removed from reality. On the other hand, the supposedly taller northern tribes may have appeared to be of exceptional height seen through the eyes of a shorter Roman citizen but, in the end, this has to remain speculative since Continental skeletal remains shortly pre-dating the 'Germanic invasion' of Britain are scarce and reliable stature calculations do not exist due to the widespread practice of cremation burial and inhumation cemeteries containing only small numbers of individuals prior to the mid-fifth century AD (Wahl *et al.*, 1998; Lucy, 2000). Nevertheless, Müller (1958; 1964) maintained the opinion that stature can be securely calculated from cremated human remains. He proposed that adult height could be calculated by means of a regression formula using the circumference of the cremated radial head. However, the reliability of this method has to be doubted. Bennike (1985) in her study of Danish skeletons found a lower stature for men dated to the Roman Iron Age when compared to men from the Germanic Iron Age. However, the contrary was observed for females. Moreover, this study used measurements from less than five female and male femora in each period and might therefore not be representative of stature changes over time. Consequently, it remains unknown whether the genetic influence of taller Germanic peoples contributed to the increase in height during the Anglo-Saxon period.

Interestingly, in a German context adult stature was used to focus on a different aspect, namely the relationship between social status and height. For the early medieval German skeletons from the row grave cemetery of Weingarten (southwestern Germany), Huber (1967; 1968) concluded that the richest male burials with grave-goods including heavy weapons such as a spatha (a single-edged long sword) and a seax (a shorter two-edged sword or long knife) contained the tallest skeletons, compared to the shorter individuals with lighter weapons (javelins and arrow heads), or the still shorter people buried without any grave-goods. Equalling 'wealth' of grave-goods with a higher socio-economic status of the buried person, it was inferred that high status individuals were taller than people of lower rank. Critically, Huber remarked that these results may be influenced by differential preservation leading to higher status burials being better preserved due to their deeper cut graves and, on a more general basis, he questioned whether the individuals buried at Weingarten were truly representative of the living population. A less critical approach was advocated by Härke (1990), who proposed that differences in male stature of early medieval British individuals buried with and without weapons were correlated with status, ignoring that the observed differences were well within the standard deviation of skeletal height measurements.

3.3 Dental disease

Dental health is an important parameter, which can be used to enhance knowledge about past people's general health. Healthy teeth are a prerequisite for any individual's physical and psychological well-being. Good dental health enables a person to consume all types of food, while poor dental health, for example dental caries and loose teeth, may lead to a monotonous, unbalanced diet, because chewing of certain foodstuffs is hindered due to pain. In turn, an unbalanced diet might lead to an impairment of health, because essential nutrients are absent (Arcini, 1999). Dental disease is, next to joint disease, one of the most often observed pathological changes in skeletal human remains and dates back to the development of early hominids, but is not exclusive to the genus *Homo*, as finds of dental caries on the teeth of extinct animals attest (Moodie, 1923; Clement, 1958).

Teeth consist mainly of inorganic calcium salts and an organic matrix; they form an important constituent of the human skeletal record and are sometimes the only surviving elements of an inhumed body. Teeth represent the hardest tissue found in living beings. They are made up of three main components: enamel (forming the outer surface of the tooth crown), dentine (underlying the enamel) and cementum (surrounding the roots). In the centre of each tooth lies the pulp cavity with its small blood vessels, nerves, cells and fibres (Cruwys and Foley, 1986). Each set of dentitions, the deciduous and permanent teeth, can yield an important amount of information about human behaviour, e.g., the use of teeth as a 'third hand', (Freeth, 2000), population affinities and origins, e.g., non-metric traits may indicate family relationships (Alt, 1989) and stable isotopes found in teeth can reveal where an individual was born (Budd *et al.*, 2003), general non-specific stress, e.g., periods of malnutrition and disease may be engraved onto the teeth in the form of hypoplastic defects (Goodman *et al.*, 1984a) and lastly, diet and subsistence, e.g., dental pathologies such as caries might provide information on the main food group consumption such as proteins and carbohydrates, as well as food preparation techniques (Larsen, 1997).

In the following paragraphs, dental pathologies comprising dental caries, calculus, periapical lesions, ante-mortem tooth loss and periodontal disease will be considered. Furthermore, enamel hypoplasia, in itself not a disease, but a sign of enamel growth disruption, will be included.

3.3.1 Dental caries

In a modern clinical dental context, dental caries is, next to periodontal disease, the most commonly encountered disease (Silverstone *et al.*, 1981) and it is routinely reported in archaeological human remains (Roberts and Manchester, 1995). Caries is a progressively advancing infectious disease, caused by microorganisms (e.g., *Lactobacillus acidophilus* and *Streptococcus mutans*) adhering to the enamel surface, where they produce a gelatinous film (Hillson, 1996). This film accumulates more and more bacteria if it is not removed by hygienic methods, culminating in a continuous bacterial layer, or plaque (Lang, 1979). The fermentation of sugars introduced to the oral cavity through the diet enables these bacteria to produce lactic acid lowering the oral cavity's neutral pH level. If this pH level sinks below 5.5, tooth enamel starts to demineralize. If the pH level rises again, re-mineralization starts. However, if food is consumed too often, pH levels cannot be restored soon enough to prevent the enamel dissolving process (Arcini, 1999; Zero, 1999). The cariogenicity of a particular diet is mainly determined by the amount of metabolised carbohydrates it contains, and among them especially sugars (Powell, 1985). Although most kinds of sugar (e.g., fructose, maltose, glucose and sucrose) have been recognized as the main causative factor in caries development, a sugar-free diet does not necessarily prevent carious cavities. A combination of sugars and starches is regarded especially as highly cariogenic (Hillson, 2000). After triggering an initial demineralization process, usually occurring on the tooth's enamel, the destruction may continue, eventually leading to a cavity. The affected person might experience more or less severe pain as the lesion develops, which can proceed into the pulp chamber and further through the periapical foramen into the alveolar bone where it forms a periapical abscess (Hillson, 1996). However, there is little evidence of how intensely past people actually suffered from toothache and we do not know whether this is comparable to our own modern perceptions of pain and discomfort.

On the other hand, certain foodstuffs such as dairy products may protect the dentition against the progressive demineralization process and the lack of carbohydrates in some diets, e.g., that of North American Inuits is linked to low caries prevalence rates (Hillson, 1996). Of all sugars, lactose stemming from milk products seems to be the least cariogenic due to its high calcium and phosphate contents, and cheeses do have a protective quality against caries (Bowen and Pearson, 1993; Garrow and James, 1993; Moynihan, 2000). Moreover, in the absence of oral hygiene, dietary fibres may help to remove plaque deposits from tooth surfaces and therefore decrease the likelihood of dental caries. Abrasion can prevent the spread of initial carious defects because of its levelling effect. Pits and fissures, in which food matter might become trapped and provide a breeding ground for bacteria, are also evened out. A coarse fibrous diet, in contrast to sticky flour-rich foodstuffs, and fine gritty particles from querns, introduced to flour while grinding corn, especially contribute to this effect (Carli-Thiele, 1996). However, high attrition is not always beneficial since a positive relationship between high attrition and dental caries has been noted for a Mesolithic population from Portugal (Larsen, 1997). High attrition may also lead to a critical loss of enamel and dentine, exposing the pulp chamber to bacterial invasion followed by inflammation of the pulpal tissues (pulpitis). A spread of this inflammatory process into the surrounding alveolar bone can culminate in a periapical lesion (see section 3.3.3).

In addition, a number of other factors may enhance or prevent caries development. Fluoride concentrations in drinking water and food of 1 ppm (parts per million) were found to be efficient to prevent the development of dental caries; this equals a daily intake of 1-3 mg of fluoride. Highest fluoride values in food are found in tea, fish, curly kale and endive, while natural fluoride contents of drinking water can vary considerably even within confined geographical areas (World Health Organization, 1994). However, the consumption of more than 6mg/day of fluoride can lead to fluorosis, which is characterized by brittle bones, stiff joints, weight loss, anaemia and weakness. In many part of the world, such as Tanzania, Kenya, South Africa, the Indian subcontinent and China, fluorosis is a major source of modern morbidity (Garrow and James, 1993). Fluorosis was also tentatively diagnosed in archaeological human remains from the United Arab Emirates and high fluoride levels in drinking water were suspected to have contributed to the development of dental fluorosis in this area (Blau *et al.*, 2002).

Excessive dosages of fluoride of over 3 ppm are likely to induce extensive mottling of tooth enamel (Kerr, 1988).

To a lesser extent other trace elements, such as molybdenum, strontium, boron and lithium are related to low caries prevalence rates, while higher selenium levels are associated with an increase in carious lesions (Powell, 1985; Garrow and James, 1993). Furthermore, certain geoclimatic variables, such as mean hours of sunshine, latitude, distance from the sea, rainfall, temperature and relative humidity are thought to play a crucial but yet ill understood role in the development of dental caries (East, 1939; Dunning, 1965; Valentine *et al.*, 1982).

Similarly, sex appears to be an influencing factor in the interpretation of dental caries frequencies and, in general, females are more often affected than males, in both archaeological and modern populations (Larsen, 1983; 1997; 1998; Lukacs, 1996). Several contributing factors for a higher female susceptibility to dental caries have been identified. Both pregnancy and earlier tooth eruption in females have been discussed as causative factors, and both have been dismissed because they were not found to be universal (Larsen, 1997). Differential eating habits might be responsible for the difference between male and female caries frequencies in most agricultural populations (Walker and Erlandson, 1986). Frequent meals or snacking between meals can lead to an oral environment with leaves teeth exposed to caries development (Weiss and Trihart, 1960; Burt *et al.*, 1988). Women may have been more likely to eat between meals due to direct access to food items during preparation and cooking. Thus, their oral pH level is less likely to return to neutral, making female teeth more prone to acidic demineralization and subsequent carious lesions. However, not all populations follow this trend of displaying a higher female caries frequency and a survey of more than 40 skeletal samples from Britain dating to the Anglo-Saxon period, no tendency towards the female sex was identified (Caffell, pers. comm.).

It is beginning to emerge that social status might influence dental caries experience. High status individuals may have had preferential access to more protein-rich diet reducing their consumption of cariogenic carbohydrates (Walker and Hewlett, 1990). On the other hand, high status food items such as honey and dried fruits, for example known from Romano-British sites, would have produced the contrary effect and the less refined food commonly associated with lower status individuals would have had a beneficial self-cleansing effect on their dentition.

Ultimately, a variety of factors may lead to the destruction of tooth enamel, dentine and cement, initiated by the acid-producing bacteria found in dental plaque. Like so often in palaeopathological analyses, frequencies of dental caries will be underestimates of the true figures. Not all demineralized focal spots will progress into carious cavities, since caries is usually a slow and chronic process, where some remineralization might take place. Potentially, these arrested caries cavities may become obliterated by dental calculus and in addition, severe attrition can equally remove existing carious lesions (Triantaphyllou, 2001). The greatest bias in dental caries studies is possibly introduced by teeth lost ante-mortem, since it cannot be known whether teeth were lost due to caries or for some other reason, including intentional extraction. The age structure and differential survival of certain tooth types of skeletal populations may also influence caries rates. Since caries is a chronic and long-standing disease, it seems to be logical to assume that the older an individual, the higher his or her caries experience would have been. However, the onset of the disease might have occurred decades before the person finally died and the relationship between advanced age and higher rates of ante-mortem tooth loss has to be considered as well. Several authors have provided us with so-called 'caries-correction factors' (Lukacs, 1995; Duyar and Erdal, 2003), but their application is not considered beneficial by all researchers (Freeth, 2000).

The age structure of the analysed population may also influence the location of carious lesions on the tooth itself. According to Aufderheide and Rodríguez-Martín (1998), two patterns have to be differentiated: crown caries and root caries. Periodontal disease leads to the exposure of tooth roots and is more likely to occur in older individuals. Consequently, more root caries will be found in elderly people, while crown caries is more restricted to younger individuals, who have not yet experienced an exposure of their roots to pathogens causing dental caries.

Posterior teeth have a higher likelihood of being infected by dental caries due to their crown morphology with pits and fissures, in which plaque can accumulate, and they frequently display high prevalence rates in teeth of past populations (Elsäßer, 2002). These teeth are also more likely to survive in the archaeological record because premolars and molars are more securely anchored into their alveolar sockets and are less prone to post-mortem loss than the anterior dentition. Subsequently, caries rates are artificially inflated due to the relative absence of caries-free incisors and canines (Hillson, 1996).

Furthermore, teeth displaying some form of developmental defect (e.g., enamel hypoplasia or fluorosis) are more often affected by caries, since the tooth's structure is already weakened and thus is more prone to develop cavities (Duray, 1990). Therefore, in populations with a high percentage of developmental defects, a high percentage of dental caries would be expected. For instance, Lewis (2002) found a positive association between enamel hypoplasia and dental disease, such as dental caries and periapical lesions, in her study of medieval British non-adults.

Until recently, a genetic predisposition for the development of dental caries has been claimed, but it is now acknowledged that diet and consequently the composition of the oral flora are mainly responsible for enhancing or inhibiting the process. Other factors, such as dental hygiene, quality of tooth enamel and dentine, and the position within the dental arcade play a crucial role. However, oral hygiene did possibly not exist during large parts of prehistoric and historic times or was non-effective (Carli-Thiele, 1996).

Buccal pits, or *Foramina caeca*, which are anatomical variants manifest as small circular indentations on the buccal aspect of molar teeth may be mistaken for caries affecting smooth enamel surfaces (Lukacs, 1989). They may also provide focal points for acidic attack and might help to initiate cavities (Pfeiffer, 1979). Moreover, post-mortem damage to teeth might mimic carious lesions. Diagenetic factors might equally act on tooth surfaces, which have been previously destroyed by caries, obliterating true cavities from the palaeopathological record.

3.3.2 Dental calculus

Dental plaque is not only related to the development of carious lesions but also to the formation of dental calculus, which is formed at the base of living plaque deposits (Lukacs, 1989). Calculus is nothing more than mineralised plaque, although the "factors that initiate mineralization are little understood" (Hillson, 2000: 259). Minerals derive from the saliva, which is excreted into the oral cavity through the ducts of the salivary glands. These are situated on the lingual surfaces of the anterior teeth and the buccal aspects of the molars, and here most calculus deposits are found (Hillson, 1996). Although multi-factorial in origin, calculus formation is initiated by an alkaline oral environment and a diet high in protein leads to an increase in alkalinity (Lieverse, 1999). In the clinical and palaeopathological literature, two types of calculus are differentiated: supragingival and subgingival. While the first is lighter in colour and adheres to the tooth crowns, the latter is found on the root surface after the gum line has receded due to periodontal pocketing, and it forms a hard and dark layer. The more common supragingival calculus is less strongly attached and it may become lost either in the burial environment or during post-excavational cleaning and curation (Hillson, 1996). This uncontrollable loss of mineralised plaque has led to the question of whether and to what extent dental calculus should be recorded in archaeological skeletal samples (Alt and Lohrke, 1998; Hillson, 2000).

In population-based studies, a tentative inverse relationship between calculus and caries has been noted, since the first is a demineralization process while the second depends on mineralization. However, both may occur on the same tooth (Hillson, 2000). Therefore, populations with high caries but low calculus rates are likely to have existed on a diet rich in carbohydrates, while the opposite suggests a high animal protein consumption. In modern populations, men usually display more severe supragingival deposits than women, but advancing age leads to an increase in frequency and extent of calculus in both sexes (Hillson, 1996).

3.3.3 Periapical lesions

Periapical lesions result from a spread of infection via the pulp chamber, which itself is exposed to bacterial infiltration, either by severe attrition, extensive carious decay or minor cracks in the enamel. Furthermore, localized infection of the alveolar bone can occur as a result of periodontal disease (Lukacs, 1989; Hillson, 1996; 2000). Although the palaeopathological literature generally refers to these defects as 'periapical abscesses', three different types of lesions have been identified. They are distinguished by size and the nature of their walls and margins and are termed periapical granuloma, apical periodontal cyst and periapical abscess (Dias and Tayles 1997). However, their differentiation can only be done reliably with the help of radiographic imaging. In the absence of radiographic equipment, the presence of a drainage sinus (fistula) might be indicative of a pus-forming process as it occurs only in periapical abscesses. Granulomata and cysts, which contain fluid or paste rather than pus, are more benign in nature (Hillson, 1986; Freeth, 2000), and are therefore unlikely to form a sinus tract. Since pus follows the path of least resistance, fistulae occur either on the buccal or lingual aspect of the alveolar process or in the floor of the maxillary sinuses.

Several problems are associated with the recognition and analysis of periapical lesions. Even if a presumed drainage canal is visible with the naked eye, care has to be taken not to wrongly identify areas of post-mortem damage. The alveolar bone associated with the maxillary canines is very thin and prone to post-mortem alterations forming pseudo-sinuses. However, edges damaged post-mortem should be sharp and are often lighter in colour than the surrounding bone. Smooth, rounded margins bearing no colour difference and the presence of pulp exposure in the associated tooth may support a diagnosis of periapical abscess (Freeth, 2000).

In clinical cases, ca. 95 percent of all periapical radiolucencies are caused by either periapical granulomas or radicular cysts. Further complications arise from the fact that abscesses might develop within cavities previously formed by granulomas or cysts (Freeth, 2000). However, Alt and co-workers (1991) deny that granulomas and cysts can be distinguished on a radiographic basis alone and reliable differentiation is only possible by histology. They further conclude that, "epidemiologically, the incidence of macroscopic findings is inconclusive, as only advanced stages are recorded" (Alt *et al.*, 1991: 169). As the average time span for the development of periapical granulomas and radicular cysts following untreated caries is six years, a high percentage of periapical lesions will not be detected by macroscopic analysis alone (Alt *et al.*, 1991). This lack of detection has obvious consequences for the analysis and interpretation of periapical lesions in palaeopathology. Kerr (2000) concluded that while 'open' (drained) abscesses usually lack severe pain and complication, confined dental abscesses or their extension into deeper areas of the neck, floor of the mouth or the facial tissues cause severe distress and may have more serious consequences such as septicaemia. However, these are the type of lesions to be missed in macroscopic analyses.

Pulp exposure and the occurrence of periapical lesions have been found to be positively correlated by several researchers (Alt *et al.*, 1991). The exposure of a tooth's pulp chamber can be the result of a non-pathological process, namely dental attrition, where the amount of enamel worn away during mastication outreaches the amount of secondary dentine laid down as a natural response to counteract this progressive loss of enamel. In addition, the pulp might become exposed to oral bacteria through minute enamel cracks or extensive carious lesions penetrating through the tooth's enamel and dentine layers.

3.3.4 Ante-mortem tooth loss (AMTL)

Dental caries, periodontal disease and severe tooth wear are the causative factors most commonly cited to explain ante-mortem tooth loss (Jiménez Brobeil and Ortega, 1991). Continuous eruption, trauma leading to enamel cracks or intentional removal for therapeutic, cosmetic or ritual purposes have also been identified as contributing to tooth loss during the life of an individual (Freeth, 2000). While ante-mortem tooth loss (AMTL) is usually straightforward to identify by the presence of a remodelling alveolar socket, long-standing loss might leave only a smoothed over portion of the alveolar arch, which might be confused with the congenital absence of teeth. However, a number of factors, such as wear facets on the opposing and adjacent teeth or available space for a tooth, can hint at the prior presence of a tooth.

Extensive tooth loss during life can have considerable consequences for the afflicted individual. Edentulous or nearly toothless jaws will display bone atrophy, resulting from a loss of bony substance. This can subsequently lead to changes in the facial musculature and even speech problems. It might also be followed by an impairment in mastication with all its consequences for the individual's health as well as degenerative changes to the temporo-mandibular joint (Aufderheide and Rodríguez-Martín, 1998). However, in cases where a tooth was lost shortly before death occurred, no remodelling progress could have taken place and the tooth would be wrongly identified as being lost post-mortem. Since this remodelling process can take up to 4-6 months, the true prevalence of AMTL is likely to be underestimated in past human remains (Herrmann *et al.*, 1989). Considerable alveolar resorption may also lead to teeth being held in place by only a small and shallow socket. If such a tooth, which is more prone to post-mortem loss, since it is not firmly anchored in its crypt, is actually lost after death, this would be misinterpreted as AMTL.

In palaeopathological textbooks and skeletal analyses, AMTL and periodontal disease are frequently dealt with as two separate entities of dental disease; the former can actually be seen as the ultimate and most severe form of the latter. Nevertheless, AMTL might occur in individuals who were not affected by periodontal disease and therefore a separate analysis is justified. However, as with other dental conditions, the identification of initial and subsequent diseases is most often not possible.

3.3.5 Periodontal disease

In modern westernized populations, periodontal disease is extremely common in adults over the age of 40 and contributes to considerable tooth loss (Roberts and Manchester, 1995). However, the presence of inflammatory alveolar bone loss is not restricted to recent studies and periodontal disease has been reported in many human skeletal assemblages, some as early as the Pleistocene Australopithecines (Ward *et al.*, 1982; Ripamonti, 1989).

The teeth of the upper and lower jaws are anchored in their sockets by the periodontal tissues, which consist of the bony alveolar process, periodontal ligaments, root cement, gingivae and mucosa (Hillson, 1996). As with dental caries, periodontal disease is of multi-factorial origin, which includes diet, oral hygiene and inheritance. Severe attrition can result in the loss of interproximal contact between neighbouring teeth, which might leave the gingival tissues prone to irritation by foreign objects such as foodstuffs, and each meal is going to worsen the problem (Aufderheide and Rodríguez-Martín, 1998). A compromised immune system, or an innate activation of the immune response triggered by certain bacteria, allows for the establishment of periodontal inflammation of some or all of the periodontal elements. According to Hillson (1996: 262), the development of periodontal disease occurs in four stages with only the final stage visible on bone, where it "is classed as periodontitis." At this point, two forms of bone loss are identified: horizontal and vertical. As this differentiation was developed for radiographic diagnosis of periodontal disease on modern patients, some problems with its classification in skeletal human dentitions were noticed (Hillson, 1996).

Horizontal bone loss describes the simultaneous loss of cortical bone on all sides surrounding a tooth, which leads to the exposure of trabecular bone and a pumice stone-like appearance of the alveolar bone. Usually several neighbouring or all teeth within the dentition are involved displaying contour changes of the alveolar crest (Clarke *et al.*, 1986; Clarke and Hirsch 1991). Vertical bone loss occurs more localized on one or two neighbouring teeth and usually affects the interproximal aspects of alveolar bone, which separates two alveolar sockets. The buccal and lingual walls may remain unaffected, although vertical and horizontal bone loss can be found in the same individual (Karn *et al.*, 1984). Both processes refer to slowly progressing and long-standing chronic developments, usually associated with advanced age. However, acute infections of the gingiva and surrounding tissues are known, although they rarely leave changes on bone (Aufderheide and Rodríguez-Martín, 1998).

The assessment of periodontal disease in archaeological specimens is commonly achieved by examining the amount of root exposure on teeth still present in their alveolar crypts and severity is scored by many researchers according to the three stages defined by Brothwell (1981). A further method is to measure the distance between the alveolar crest and the cemento-enamel junction. A distance below 2 mm is considered as normal, while more than 2 mm is seen as pathological (Alt and Lohrke, 1998). However, both methods of quantifying periodontal disease and the diagnosis of the disease process itself are problematic due to the naturally occurring continuous eruption of healthy teeth.

Continuous, or continuing, eruption of teeth has been identified as introducing a major hazard in the assessment of skeletal populations' periodontal status (Danenberg *et al.*, 1991). As tooth attrition progresses, mandibular second premolars and molars continue to erupt. The same process, albeit less marked, was found to exist in the maxillary area of the second premolar and molars (Glass, 1991). However, this observation is by no means a recent one as a distinction between physiological bone recession and pathological bone resorption by Wood-Leigh (1935) on ancient Egyptian dentitions demonstrates. Despite this early recognition, continuous eruption, along with post-mortem damage of the alveolar crest and other alveolar lesions of pulpal origin, are likely to have led to a severe overestimation of periodontal disease in many palaeopathological reports (Kerr, 2000).

3.3.6 Enamel hypoplasia

Described as a non-specific indicator of stress, enamel hypoplasia has been recognized in prehistoric and historic human teeth from a wide variety of geographical backgrounds (Goodman and Song, 1999). The defect itself can be regarded as the body's response to certain insults. Enamel is produced by ameloblasts by secreting a matrix, which subsequently becomes mineralised. This matrix is laid down in distinctive bands separated by brown striae of Retzius. Since tooth enamel is highly sensitive to metabolic disturbances, matrix formation might slow or stop altogether resulting in an enamel deficiency (Goodman and Rose, 1990). Only when tooth growth continues, e.g., after the disturbance is survived, does a hypoplastic defect manifest itself (Larsen, 1997). Tooth enamel formation occurs at specific times for specific teeth and therefore the age at which a defect was formed can potentially be assessed. Since these defects do not become remodelled, in fact they can only become obliterated by severe attrition of the tooth crown or tooth loss, they form a retrospective image of stresses and disturbances which occurred during an individual's early years of life (Cucina *et al.*, 2000). Alt and Lohrke (1998: 43) have even described enamel hypoplasia as the "archive of childhood." However, a multitude of factors can lead to hypoplastic defect formation and "virtually any environmental factor leading to metabolic disturbance will result in visible changes in the structure of enamel" (Larsen, 1997: 44). Enamel hypoplasia might be the result of malnutrition or acute disease, endocrine disorders, congenital syphilis, local infection or fluorosis (Marcsik and Baglyas, 1988; Watson, 1994). Additionally, localized trauma and hereditary anomalies might produce similar defects, although they are thought to be rarely responsible and the vast majority of defects are formed due to systemic disturbances (Goodman and Rose, 1991). To eliminate trauma as an origin of enamel hypoplasia some researchers have suggested counting only defects occurring on more than one tooth. Animal studies and observations on modern populations have revealed the widespread nature of underlying disease and disruptions, which range from starvation and malnutrition, to infections, low birth weight and birth trauma as well as parasite infestation (Hillson, 1996; Lewis and Roberts, 1997). However, studies of modern patients have revealed that some individuals appear to be more susceptible to stress and will develop hypoplastic defects, while others, undergoing similar stresses, will not show enamel defects (Neiburger, 1990). This might be paralleled in archaeological populations and it cannot be assumed that all stress episodes have led to the production of enamel hypoplasia in human skeletal material (e.g., Dobney and Goodman, 1991).

To obtain a chronological distribution of hypoplastic defects, several methods have been developed (Hodges and Wilkinson, 1990). Usually, measurements are taken from the defect to the cemento-enamel junction (CEJ), which then become converted into biological age. Standard tables detailing the percentage of crown formation into which the defect falls were developed by Goodman and co-workers (1980) based on Swärdstedt's (1966) earlier study. The work of Goodman and colleagues resulted in the publication of the following formula to calculate age at which a defect occurred:

> "Age at formation then equals the negative of the rate of enamel development (in the inverse of mm per year) multiplied by the distance of the defect from the CEJ, plus the intercept (the age of crown completion)" (Goodman and Rose, 1990: 97).

This rather awkward method, in combination with the small sample size on which the original study was based, has led to criticism (Haidle, 1998). Several other assumptions have been questioned lately, especially the comparability of modern healthy populations with potentially diseased ancient individuals and the proposed similarity in tooth developmental rates between different populations (Lewis and Roberts, 1997). Furthermore, the negligence in accommodating differences in crown height between different populations which might introduce further problems with comparability has been addressed, and consequently a revised method was proposed by Hodges and Wilkinson (1990) which considers crown height differences.

A peak in hypoplasia development has been noticed in individuals between two and four years of age (Lanphear, 1990; Wright, 1990). This has been attributed to stresses acting on children who undergo weaning. Due to changes in the quality and quantity of their diet, so-called 'weanling diarrhoea' could have had a severe impact on the child's health (Fildes, 1995). Additionally, at this point in life, their immune system is no longer protected by breast-feeding and the rapidly occurring growth makes them more susceptible to environmental stress (Saunders and Hoppa, 1993). Alternatively, other non-pathological factors such as the exhaustion of ameloblasts, dental morphology and enamel layer patterning may also have contributed to the formation of hypoplastic defects during this specific time period (Hodges and Wilkinson, 1990; Hillson and Bond, 1997).

3.4 Joint Disease (Arthropathies)

There are several hundred joints or bone articulations in the human body, of which 190 are synovial joints and without them even simple movements would be impossible. The number of diseases directly affecting joints is correspondently high and in standard clinical textbooks more than 250 different arthropathies are differentiated (e.g., Resnick and Niwayama, 1988). In palaeopathology, they are usually diagnosed by typical bone reaction, either as new bone formation or erosion or both, and characteristic patterning of joint involvement. For example, rheumatoid arthritis typically affects the metacarpophalangeal and proximal interphalangeal joints, as well as the corresponding foot joints in a symmetric way, while ankylosing spondylitis presents, among other features, with symmetrical ankylosis of the sacro-iliac articulation (Rogers *et al.*, 1987; Kissane, 1990). Arthropathies are exceedingly common in modern populations and they were also highly prevalent in the past. Roberts and Manchester (1995) outlined a classification system for joint diseases according to causative factors: neuromechanical, inflammatory, metabolic and auto-immune. Osteoarthritis is a representative of the first group, while septic arthritis has an inflammatory origin. Rheumatoid arthritis, ankylosing spondylitis and psoriatic arthritis are also inflammatory in nature but they are usually described as diseases of the immune system, together with Still's disease (juvenile rheumatoid arthritis), Reiter's syndrome and diffuse idiopathic skeletal hyperostosis (DISH). Gouty arthritis is an example of metabolic disease induced by the deposition of urate crystals in a joint and its subsequent inflammatory response. However, in the absence of modern diagnostic tools, for example serology, the differentiation between certain types of joint disease may be difficult or even impossible, especially when soft tissue changes are part of a disease syndrome.

Additionally, several different types of joint disease may be present in the same person. For example, Waldron found osteoarthritis in conjunction with rheumatoid arthritis in a post-medieval female skeleton from London (Waldron *et al.*, 1994). Furthermore, incompletely preserved skeletons may hinder the assessment of distribution patterns typical of a specific joint disease (Rogers *et al.*, 1987).

The arthropathies identified in the study samples were osteoarthritis, degenerative disk disease and Schmorl's nodes. Schmorl's nodes appear on the superior and inferior aspects of vertebral endplates as indentations caused by the collapse of an intervertebral disk (Schmorl and Junghanns, 1968; 1971). Degenerative disk disease also occurs on vertebral endplates; it is caused by degeneration of the fibrocartilaginous intervertebral disk (Rogers and Waldron, 1995).

3.4.1 Osteoarthritis (OA)

Osteoarthritis (OA) is defined as "an idiopathic disease characterized by a degeneration of articular cartilage" (Martel-Pelletier, 1998: 374). This definition can be extended to "a noninflammatory disorder of movable joints characterized by deterioration and abrasion of articular cartilage, and also by formation of new bone at the articular surface" (Sokoloff, 1969: 2). In fact, 'osteo' is the Greek word for bone, while 'itis' is the Greek suffix for inflammation and the term 'osteoarthritis' is frequently described as a misnomer, since it does not entail an inflammatory process of bone tissue (Sokloff, 1969; Kissane, 1990). However, in clinical studies, secondary inflammatory reactions of the synovial membrane, which forms the inner layer of the joint capsule, are often observed and these findings may justify the usage of this specific term (Pelletier *et al.*, 1997). Nevertheless, a whole array of names have been given to the condition, which can occur on any synovial joint – degenerative joint disease, degenerative arthritis and arthritis/arthrosis deformans, to name only a few (Herrmann *et al.*, 1989; Aufderheide and Rodríguez-Martín, 1998). In this study, osteoarthritis and degenerative joint disease will be used interchangeably.

Despite its considerable antiquity, relatively little is known about the aetiological factors causing osteoarthritis, nor is it known how the condition may be prevented. OA has been reported in extinct cave bears and Neanderthal skeletons and it occurs in almost every archaeological skeletal human population (Virchow, 1895; Moodie, 1923; Jurmain and Kilgore, 1995). Its high prevalence in Danish skeletons from all periods has led Bennike (1985: 123) to remark that "people in prehistoric times were terribly rheumatic." However, OA is by no means restricted to past populations, and today approximately 10 percent of modern individuals are suffering from degenerative joint disease (Bullough, in press). In fact, it is now the most common disease affecting the skeletal system (Zilch and Weber, 1989). OA increases in frequency with age, which indicates it is a progressive disease that takes years to develop (Apley and Solomon, 1990). There seems to be no single cause for osteoarthritis. 'Wear and tear' in the form of stress applied to articular cartilage and the disability of the cartilage to withstand that stress results in degenerative joint disease. However, weak cartilage, poor subchondral bone, trauma and overuse may all contribute to the development of OA and heredity has to be considered, at least in some patients (Prockop, 1999). Other factors include obesity and high cholesterol levels or trauma due to fracture and dislocation and poorly healed fractures (Roberts and Cox, 2003). A simple classification applied in clinical medicine comprises of primary and secondary osteoarthritis: the first is used when no apparent cause is evident apart from ageing, and the latter when osteoarthritis is secondary to another condition (Zilch and Weber, 1989; Kissane, 1990). In a modern context, the weight-bearing joints of the hip, knee and spine are more often affected than, for example, the elbow (Apley and Solomon, 1990). Present-day women and men are suffering from degenerative joint disease in approximately equal proportions. Nevertheless, specific joints such as the distal interphalangeal joints of the hand and the knee joint are more often involved in women. Furthermore, under the age of 55 years, men are more likely to display OA, while postmenopausal women are more susceptible, indicating that hormonal factors might be responsible (Riede and Schaefer, 1999).

Only a limited range of bony responses, bone proliferation and erosion, can be found in any bone disease and OA is no exception to this. Clinical features of degenerative joint disease comprise osteophyte formation on the joint margin or joint surface itself, pitting of the joint surface, subchondral cysts, joint contour change and eburnation. However, apart from eburnation, which is pathognomonic of OA, these features might also be part of other types of joint disease (Rogers and Waldron, 1995). Eburnation is the result of bone-to-bone contact following the destruction of cartilage and continuous joint movement, which can lead to grooving on the already polished surface of hinge joints, such as the humero-ulnar joint of the elbow. Morphologically, marginal osteophytes can represent the joint's attempt to provide stability. However, they might be part of the normal ageing process, especially in the absence of other changes (Rogers and Waldron, 1995; Rogers, 2000). Pits on the articular surface can communicate with underlying subchondral cysts, which in the living person are filled with synovial fluid

(Kissane, 1990). In the absence of pitting or post-mortem damage revealing subchondral cysts, only radiographs can confirm their presence. However, the pathological nature of surface pitting has been challenged lately (Rothschild, 1997) and radiography is not commonly employed to investigate all joints in archaeological material.

In addition, climate might also be a predisposing factor, although osteoarthritis occurs in all climatic zones. Nevertheless, symptoms can be more prevalent in colder and wetter regions, for example in Northern Europe (Larsen, 1997). Pain is the single most often reported symptom in OA, but increasing stiffness of a joint may decrease the amount of pain experienced by the patient, because the joint cannot be moved anymore. Furthermore, swelling and deformity may contribute to considerable discomfort and an estimate of many millions of workdays missed due to the disease points to its magnitude in modern populations (Sokoloff, 1969). Interestingly, it has been recognized that the clinically observed severity of osteophyte formation does not necessarily reflect the amount of pain or disability a patient encounters (Jurmain, 1999). For this reason, Rogers and Waldron (1995: 102) have argued against grading severity of osteoarthritis in archaeological human remains since evaluations of "the severity of disease – from the appearance of a joint are wasteful and can serve no useful purpose."

Modern medical examiners are usually confronted with patients reporting to them with localized pain in one or more joints. This self-reported diagnosis of OA is frequently confirmed by radiographs, assessing the amount of joint space narrowing and osteophyte formation, followed by a treatment targeting pain relief, improving mobility and reducing weight (Apley and Solomon, 1990). Naturally, this form of diagnosis is inaccessible to the palaeopathologist who, through the direct observation of joints, can detect even minor bone changes. However, there are certain problems with the diagnosis of osteoarthritis in skeletal human remains. Joint alterations due to osteophyte formation can also be found as a non-pathologic part of the ageing process. Consequently, the recording of new bone formation at joint surfaces alone may lead to a severe overestimation of the disease, especially in a skeletal population with many elderly individuals and controlling data for age is a requirement. Furthermore, because of the differences in clinical and palaeopathological diagnostic methods, the observed frequencies of OA between modern and ancient populations are not necessarily comparable. However, palaeopathological reports of degenerative joint disease may be equally incomparable because of the use of different diagnostic criteria. It is mostly agreed that the more stringent criteria outlined by Rogers and Waldron (1995), which rely on the presence of eburnation, should be used, or in the absence of this at least two of the following should be present for diagnosis: osteophytes on or around the articular surface, porosity or subchondral cysts. However, some researchers consider any one of these changes as indicative of osteoarthritis (e.g., Duhig, 1998). Comparing prevalence of degenerative joint disease in archaeological populations is further hindered by the inclusion of different joint surfaces when evaluating complex joints. For example, the shoulder joint can consist of the humeral head and the glenoid fossa of the scapula only. Alternatively, the acromio-clavicular joint may be included, which would lead to a change in prevalence rate since the latter is more commonly affected than the former (Rogers, 2000).

Apart from diagnostic problems and comparability of data, the interpretation of osteoarthritis frequencies in archaeological skeletal populations is hindered by the fact that degenerative joint disease is a multi-factorial condition. However, a possible connection between the development of osteoarthritis of specific joints and specific occupations found in some modern studies, has lead to the belief among palaeopathologists that activities of ancient populations can be inferred from the observation of degenerative joint disease. For example, pneumatic drill operators are more prone to develop OA in their shoulders and elbows than their non-drilling peers (Meiss, 1933; Radin *et al.*, 1972), while ballet dancers and football players are likely to display degenerative disease of the talar joints (Sokoloff, 1969). This association of specific repetitive movements with the degeneration of a specific joint has been applied to archaeological human remains. Merbs (1983) in his study of a Canadian Inuit group, the Sadlermiut, suggested to explain certain patterns of osteoarthritis with specific sex-related tasks. For example, the high prevalence of temporo-mandibular joint disease in female Sadlermiut was due to softening animal hides by chewing on them and male shoulder joint degeneration was caused by paddling kayaks. As these, and other activities, were observed ethnographically, an analogous interpretation seemed reasonable to Merbs.

However, there a numerous problems with this form of interpreting degenerative joint disease in any skeletal data. Naturally, it is very appealing to the palaeopathologist to explain patterns of a disease which is so commonly encountered as osteoarthritis in terms of human behaviour and activity, and Wells (1982: 152) has called osteoarthritis "the most useful of all diseases for reconstructing the life style of early populations." Although there are countless modern examples of occupational-induced cases of degenerative joint disease, these observations are mostly of anecdotal nature and are not applicable to palaeopathology (Jurmain and Kilgore, 1995). In archaeological human populations a non-random sample of the once living population is buried, and although intrinsic and extrinsic factors determine which skeletons survive to be analysed, osteoarthritis is most likely not among these factors introducing bias. However, palaeopathological observations assess people's health status after they have died and the question of when a person developed joint disease cannot be answered. In contrast, modern patients tend to seek a doctor's help when pain and other discomfort occurs in a joint, thus entering the statistics. Nothing is known about joint disease prevalence in symptomless individuals, as routine radiograph inspections would be unethical. Here, analyses of dissection room cadavers might provide insights in OA prevalence and patterning of individuals with known professions. However, findings from a recent study of skeletons from early modern Christ Church, Spitalfields, London for whom age, sex and profession were known introduced some doubt. Despite the fact that many individuals were employed as silk weavers, a task associated with joint degeneration of the hands, no statistically significant difference was found between weavers and people with other occupations (Waldron, 1994).

3.4.2 Degenerative disk disease (DDD)

Joints of the vertebral column consist of two different types – apophyseal facet joints are synovial joints and their degeneration should be considered as osteoarthritis. However, articulations between vertebral bodies are formed by fibrocartilaginous disks and their degeneration can result in osteophyte formation at the margins of vertebral bodies, as well as roughening and pitting of the vertebral endplate. The intervertebral disks, which are highly flexible in youth, increasingly lose their ability to cushion the underlying bone against mechanical stresses, and additionally to the described changes, sclerotic areas and even eburnation may occur on the margin of the affected vertebral bodies (Zilch and Weber, 1989). In German palaeopathological reports, this is sometimes known as "*Osteochondrosis vertebralis*" (Hollack and Kunter, 2001: 455). Nevertheless, synonyms for this condition are diverse; known as degenerative or intervertebral disk disease, spondylitis deformans and vertebral osteophytosis, the first is favoured in the present study.

Again, there is a problem with consistency of diagnosis in archaeological human skeletal remains as some researchers regard osteophyte formation on vertebral body margins in itself as diagnostic of 'vertebral osteophytosis' (e.g., S. Anderson, 1996; Hukuda *et al.*, 2000). However, Rogers and Waldron (1995: 27) identify vertebral osteophytosis "by coarse pitting, sometimes associated with new bone growth, on the superior or inferior surfaces of the vertebral bodies," although marginal osteophyte formation is an "almost invariable accompaniment." However, this appears to be a contradiction, since the very name implies the presence of osteophytes and for this reason the term degenerative disk disease (DDD) is preferred in the current study, although osteophytosis is more widely used in the palaeopathological literature. According to Rogers and Waldron (1995), degenerative disk disease occurs more commonly in the mid and lower cervical, upper thoracic and lower lumbar vertebrae, either on one or both surfaces of the vertebral endplates. There seems to be a relationship between the natural curvature of the spine and the predilection of these spinal regions (Jurmain, 1999). The aetiology of DDD is also attributed to intervertebral disk degeneration due to the stress of weight bearing and, like osteoarthritis, it has been attributed to specific behaviour (Maat *et al.*, 1995). However, DDD is also an age-related disease and other factors such as sex, weight, ancestry and mobility have been cited to contribute to disk degeneration (Rogers *et al.*, 1987; Waldron, 1991b; 1992b; 1994).

3.4.3 Schmorl's nodes

Described independently by W. Putschar and G. Schmorl in 1927 (Putschar, 1927a; 1927b; Schmorl, 1927), the latter was a German pathologist whose name was eventually given to small indentations often observed in superior and inferior vertebral endplates of modern and archaeological human skeletal remains (Jurmain, 1999). Schmorl's nodes can be regarded as a more localized form of intervertebral disk degeneration caused by herniation of the inner part of the jelly-like disk (*nucleus pulposus*) through weakened areas in the outer fibrous ring (*annulus fibrosus*). They appear to be more prevalent on inferior endplates and are attributed to a variety of possible aetiologies, such as infectious, neoplastic and metabolic disease weakening of the intervertebral disk (Schmorl and Junghanns, 1968; 1971). Additionally, childhood trauma may play an important role and Schmorl's nodes are clinically associated with Scheuermann's disease, an adolescent kyphosis classified as osteochondrosis (Zilch and Weber, 1989; Jurmain, 1999).

Jurmain (1999) explained Schmorl's nodes primarily as developmental in origin and argues that as they are so frequent, they should be regarded as 'normal'. He noted that some specific behaviour, such as lifting heavy objects, has been attributed to archaeologically observed cases of Schmorl's nodes. However, in the light of their common occurrence in non-human primates, this factor seems to be poor at explaining the presence of Schmorl's nodes in apes as is hard to imagine any weight-bearing activities undertaken by wild gorillas and chimpanzees. Furthermore, there has been no compelling evidence for an association between lifting heavy weights and Schmorl's nodes. Jurmain (1999: 168) recommended that due to a lack of clinical support "even general behavioral interpretations" or more detailed hypotheses such as the lifting of heavy objects should not be attempted when analysing Schmorl's nodes in human skeletal remains.

3.5 Trauma

Evidence for skeletal trauma has a long history in palaeopathological studies and a vast body of descriptive and interpretative analyses have been published (e.g., Merbs, 1989a; Bennike, 1985; Lovell, 1997a; Roberts, 1988; 1991; 2000a). Merbs (1989a: 161) surveyed all aspects of skeletal trauma and its possible causes, stating that trauma "occurs as a result of violent encounters with environmental hazards, inter and intraspecies conflicts, and in rare instances, self-mutilation and suicide." Although in archaeological studies of human skeletal remains trauma is commonly used as a synonym for fractures, joint dislocations, weapon wounds and surgical intervention, such as trepanation and amputation, are also frequently included in studies of skeletal trauma. Furthermore, some authors add artificial cranial deformation, exostoses, osteochondritis dissecans, scalping and growth arrest lines to trauma (Lovell, 1997a: Table 1). In the present context, the following categories will be discussed under the heading of skeletal trauma: post-cranial fractures, cranial trauma and spondylolysis. The latter has not been included in the previously described categorization by Lovell (1997a), but spondylolysis is thought to be caused by repetitive stress and is often seen as a stress fracture in combination with an underlying congenital weakness (Roberts and Manchester, 1995). Despite the variety of traumatic injuries, this is likely to represent only a proportion of the actual encounter with physical injuries experienced by individuals from the study populations as soft tissue trauma may not become visible on bone. Moreover, long-standing injuries, for example those sustained in childhood, may remodel completely and become undetectable.

3.5.1 Fractures

Bone fractures are both common and usually easily recognized in skeletal remains. Possibly the oldest example of a bone fracture was dated to the Permian and involved the left radius of Dimetrodon, a dinosaur found in Texas (Moodie, 1923). In 1858, the German anatomist and physician H. Schaafhausen described a healed fracture of the left olecranon observed in the eponymous human skeleton from the Neandertal near Düsseldorf (Schaefer, 1957). Despite the great interest in fractures and their possible interpretation with regard to injury mechanism and treatment during the nineteenth and twentieth centuries, the study of fractures remained focused on case studies. One early exception was the analysis of skeletal populations from Egypt and Nubia detailing information on fracture frequency for individual bones (Wood-Jones, 1910). However, this study remained unrivalled until the early 1980s, when Lovejoy and Heiple (1981) published their fracture study of prehistoric Native American Indians from the Libben site in Ohio. Since then a growing body of population-based fracture analyses of archaeological human remains have been conducted, spanning several different geographical areas as diverse as the United States (e.g., Jurmain, 1990; Jurmain, 2001), the Sudan (e.g., Burrell *et al.*, 1986; Kilgore *et al.*, 1997; Alvrus, 1999; Judd, 2001) and England (e.g., Grauer and Roberts, 1996; Judd and Roberts, 1999). Different time periods have been analyzed, including Neandertal skeletal remains (Berger and Trinkaus, 1995), the Neolithic (Angel, 1974) and medieval periods (Stirland, 1996). Recently, long bone fracture patterning has been studied with respect to diachronic trends within skeletal populations from the same geographical area, contrasts between inhabitants of urban and rural regions (Judd and Roberts, 1999), the evidence for trauma treatment (Roberts, 1988; 1991; 2000a), as well as the effects of certain diseases such as leprosy on trauma (Judd and Roberts, 1998). Interestingly, systematic studies of fracture patterns are less abundant in Germany; for example, the majority of presentations at a conference on traumatology involved cranial injuries but there was only one population-based study on rib fractures (Teschler-Nicola, 1995). However, studies of heterogeneous skeletal populations spanning large periods of time collected from a wide geographical area have been published by German researchers (e.g., Grimm, 1959; 1973; 1980; Kunter, 1974b).

Contrary to cranial and long bone fractures, injury to other skeletal elements has received far less attention in palaeopathological analyses. There might be several reasons for the absence of data on fractures other than the skull and long bones in most studies of archaeological human remains. Firstly, fractures of certain skeletal elements are rare today and they might have been in the past. Patellar fractures comprise approximately 1 percent of all fractures in clinical studies; this makes them as rare as fractures of the scapula (Baumecker, 1938). In addition, regions of the scapula, especially the blade, are fragile and might not survive well in the burial environment, therefore reducing the possibility of observing potential fractures. Some fractures caused by repeated stress can manifest as hairline cracks, for example on the diaphyses of metatarsal bones, and would be easy to miss in the absence of noticeable callus formation. Contrary to this, other skeletal elements such as specific carpal (scaphoid and triquetral) and tarsal (calcaneus) bones, as well as metacarpals, metatarsal and phalanges are commonly fractured in a modern context (Lovell, 1997a). Fractured vertebrae and ribs are also frequently encountered today and there is no reason why they should have been less frequent in past populations. However, one major reason for severe bone fractures was absent before the turn of the twentieth century – many modern patients suffering fractures are likely to have been involved in road accidents, as either pedestrians, drivers or passengers in motorized vehicles, where in severe cases a multitude of fractures may be sustained. Nevertheless, daily activities in a non-motorized setting would have left plenty of potential hazards to induce fractured hand and foot bones. However, the majority of skeletal reports, although detailing long bone fractures, do not give prevalence rates for fractures of 'minor' bones, making their relative scarceness or abundance hard to evaluate.

"Fractures are the result of any traumatic event that leads to a complete or partial break in the continuity of bone" (Roberts, 2000a: 337). Types of fractures can be named after the person who first described them (e.g., Colles, Bennett), by their appearance or anatomical position (e.g., transverse, green-stick, epicondylar, diaphyseal), by the forces that produced them (e.g., avulsion, compression), or according to activities with which they are associated (e.g., marching, clay shovelling). Fractures can be complete or incomplete, compound or closed, indicating that the fracture site was exposed to the external environment or not. In the case of an open fracture, pathogens such as bacteria could easily enter the wound and lead to infection (Roberts, 2000a). While most fractures are acute, pathological breaks might occur when the bone is already weakened by an underlying pathological condition, e.g., osteoporosis or malignant tumours (Zilch and Weber, 1989; Aufderheide and Rodríguez-Martín, 1998). Additionally, repeated minor stresses may also induce fractures (Kissane, 1990).

Direct trauma is identified when the fracture occurs at the point of impact, resulting in a transverse, penetrating, crush or comminuted fracture; for example, a blow to one's shin, if enough force is applied, will probably lead to a transverse fracture line perpendicular to the longitudinal axis of a bone (Lovell, 1997a). Penetrating trauma may result from piercing, cutting or scraping, either completely or partially penetrating the affected bone by objects such as arrows and spearheads, bladed weapons or bullets. Scraping, drilling or cutting of cranial bones might imply the surgical removal of a piece of bone as seen in trepanations. However, perimortem penetrating injuries might be difficult to identify in archaeological skeletal remains, since they can be confused with post-mortem damage. When a bone is broken into more than two pieces, the fracture is termed comminuted. This can occur as a consequence of direct or indirect trauma. Equally, crush fractures might be initiated by direct or indirect trauma. Strong vertical forces might lead to crushed vertebral bodies, where the anterior aspect becomes compressed and the overall shape of the vertebra appears as a wedge (Apley and Solomon, 1990). More uniform compression results in a so-called 'concertina' fracture, usually in elderly adults. 'Fish-vertebrae' are similar to 'concertina' fractures, but here the intervertebral disc compresses the central aspect of the vertebral body surface. This fracture type is associated with osteoporosis where the trabecular structure of the vertebra is already weakened and more prone to succumb to compression forces (Merbs, 1989a). Non-osteoporotic compression fractures of vertebrae are associated with falls or bumpy rides on vehicles lacking suspension (Grimm, 1959). Some confusion exists when differentiating between compression and depression fractures – a depressed fracture is initiated by forces applied to only one side of the bone, while compression fractures requires forces from two sides. However, although strictly speaking a blow to the head results in compression of the diploë, conventionally this is referred to as a depression fracture (Merbs, 1989a).

Indirect trauma, where fractures do not occur at the point of impact may cause spiral or oblique fracture lines. Likewise, greenstick, impacted and avulsed fractures are likely to be due to indirect forces. An oblique fracture, where the fracture line lies in a non-perpendicular angle to the longitudinal axis of the bone, implies the combination of angulated and rotated forces, while spiral fractures are due to rotation with one end of the bone being fixed in position. Today, this is frequently seen in patients who suffered a fall in downhill skiing with the binding holding the ski in place with the lower leg twisted during the tumble. Greenstick fractures are more common in children than adults, because immature bones are more flexible and bend easily without breaking, thus forming a bulge that might completely remodel over time (Stuart-Macadam *et al.*, 1998; Glencross and Stuart-Macadam, 2000). Rarely, bones become impacted; for example, during a fall on the outstretched hand the proximal humerus becomes driven into the diaphysis (Roberts, 2000a).

Stress or fatigue fractures result from sustained stress or repeated microtrauma. They occur as incomplete fractures usually perpendicular to the long axis of a bone and if the recurring stress is not eliminated it might develop into a complete fracture (Lovell, 1997a). Fatigue fractures were initially associated with the military where soldiers spend long hours on their feet and the term 'march' fracture does reflect the belief that prolonged marching can lead to stress fractures, especially affecting a metatarsal, calcaneus, or tibia (Zilch and Weber, 1989). Today, different activities are equally linked to stress fractures; ribs may break due to carrying heavy loads over the shoulder or they might fracture due to repeated coughing. Athletes such as runners, jumpers, ice skaters and ballet dancers as well as people with professions that require excessive standing, e.g., nurses and salespeople, are prone to stress fractures. Likewise, pregnant women are at risk because of the extra weight they are carrying (Merbs, 1989a).

Fractures secondary to underlying pathology most frequently occur due to metabolic disease such as osteoporosis, where the quantity of bone mass is reduced because the balance of bone resorption and formation is skewed in favour of resorption. Moreover, nutritional deficiencies might also enhance the resorption of bone, leaving them prone to fracture. Malignant bone tumours can also alter the integrity of bone and fractures may occur through or nearby a tumour. Furthermore, spinal tuberculosis might lead to the collapse of one or more vertebrae (Lovell, 1997a).

Fracture healing involves six overlapping stages: six to eight hours after the injury blood of the haematoma coagulates, and immature connective tissue develops within the blood clot, gradually transforming into fibrous callus. Fibrous callus is eventually replaced by primary bone, followed by secondary callus and finally functional reconstruction. Usually, the callus size increases from four to six weeks after the accident, and then begins to decrease. Primary bone callus rarely survives in archaeological contexts and is difficult to see on radiographs. The length of the healing process is influenced by the age of the individual. In young children, healing is more rapid than in adults. The type and severity of the fracture is also of importance; compound fractures that have become infected usually take longer to heal (Merbs, 1989a; Aufderheide and Rodríguez-Martín, 1998; Nerlich, 1998).

Healed fractures can be readily visible on bone either because some amount of callus is still present and/or some deformity had occurred. However, some fracture sites might become entirely remodelled, thus rendering them invisible to macroscopic detection.

Perimortem fractures might be hard to detect due to the lack of callus formation and they might not be distinguishable from post-mortem damage. Healing might be unsuccessful, resulting in non-union of the fractured elements. A moveable joint can form (pseudoarthrosis), indicating that there was no, or not enough, immobilisation of these skeletal parts. The presence or absence of deformity (angulation, rotation and overlap) in fractures has been used to evaluate the existence or quality of treatment, but one has to bear in mind that fractures might unite without medical intervention as was observed in wild apes (A. H. Schultz, 1967; Jurmain, 1989; Lovell, 1990; Lovell, 1991). Soft-tissue injury might coincide with bone fractures, resulting in nerve damage or disruption of blood supply, paralysing or incapacitating the affected limb. Subsequently, disuse atrophy can alter the internal structure of bone, making it more susceptible to pathological fracture. However, even a well healed fracture might lead to secondary osteoarthritis in nearby joints by altering their biomechanical properties, leading to joint incongruence (Merbs, 1989a; Zilch and Weber, 1989).

Certain limitations to the study of trauma in skeletal human remains have to be acknowledged. As previously mentioned, some fractures might be missed during analysis, even with the help of radiographs, because they are well remodelled or in the case of perimortem injury, they can be mistaken for post-mortem alterations. The fracture mechanism might not be obvious in all cases, leaving the cause, for example intentional violence or accidental injury, unknown. However, fracture patterning might provide some insight on causation, since in interpersonal violence the cranium, face, neck and lower arms are likely to be targeted (Roberts, 2000a). In incomplete skeletons, the assessment of such patterns might be hindered. This is especially true for the more fragile facial bones, which do not survive well, and for this reason some evidence for intentional injuries will not be found in archaeological human remains. Moreover, specific fractures can have more than one cause. In the case of ulnar fractures, these might be interpreted as 'parry' or 'nightstick' fractures, where the arm is raised in response to an attack to the face. Likewise, fractures of the ulna can occur as a consequence of falls on the outstretched hand (Smith, 1996; Lovell, 1997a).

One of the most fundamental problems with the interpretation of healed fractures concerns the age of when the fracture happened (Roberts, 1991). Therefore, a well healed fracture of the distal radius (Colles' fracture) might have occurred decades before the person died. However, today the most commonly part of the population affected by this kind of fracture are elderly women, who fell on their outstretched hand during a forward fall (Roberts, 2000a). In a modern clinical study of emergency departments in the Swedish town of Malmö children of both sexes and women over the age of 50 years had the highest prevalence of distal radius fractures (Graff and Jupiter, 1994).

3.5.2 Cranial injuries

"Analysis of weapon-related trauma on the human skeleton can provide valuable information on interpersonal relations in the past" (Boylston, 2000: 357). Patterns of violence and warfare vary with social context and the quality of the weapons used. The outcome or injury is dependant on the material the weapon is made of (e.g., wood, stone, metal), the mode of fighting (e.g., on foot, from horseback) and the form of protective clothing worn to prevent these injuries (e.g., helmets, armour).

Weaponry in the early medieval period was somewhat restricted when compared to the extensive arsenal known from later medieval times. Grave finds from Britain and the Continent yielded evidence for swords, knives and axes, as well as arrowheads and spearheads (Christlein, 1979; Menghin, 1983; Härke, 1989). Of course, less elaborate objects such as stones or wooden sticks could have been used as weapons. Little archaeological evidence of protective clothing has been found so far (Härke, 1990), but shield buckles were relatively frequent finds in graves from Britain and Germany (e.g., Härke, 1989). Protective headgear was likely to be reserved for members of the elite (Steuer, 1987). One example of a helmet made of individual iron lamellas comes from Niederstotzingen, southwestern Germany. This cemetery was unusual in its number of wealthy finds and was interpreted as the burial ground of a high ranking family (Paulsen, 1967). Warfare is mentioned often by Roman writers and vast numbers of Germanic warriors were supposedly killed in battle against Roman troops. However, more detailed information on battle techniques is neglected. Nevertheless, Agathias, a sixth-century AD historian from Asia Minor, reported on an unsuccessful military campaign of Frankish and Alemannic troops in mid-sixth-century Italy (Dirlmeier and Gottlieb, 1978). According to Agathias, their weapons were simple, comprising swords, axes, spears and shields. Greaves and other armour were unknown and helmets were only used by a few people (Dirlmeier and Gottlieb, 1978).

Ultimately, the possibilities of inflicting injury on another human being are endless and it should be remembered that a weapon could often be used in different ways, and therefore produce different kinds of injury. The pointed tip of a sword, for example, may leave a puncture wound, while the sharp-edged blade will produce a linear cut.

Additionally, the handle may be used as a blunt weapon. Before the introduction of firearms in the late medieval period, weapon injuries were comparatively less severe. However, lethal injuries might have been missed in archaeological remains, since perimortem fractures are difficult to distinguish from post-mortem breaks (Ortner and Putschar, 1985). Living bone tissue is remarkably resistant to fracturing, but variation in appearance might occur even within the same bone as thickness varies (Boylston, 2000). Nevertheless, not all cranial trauma is necessarily caused by intentional acts of violence and accidental injury has to be considered, especially in cases of blunt trauma. However, this differentiation is not always straightforward as Merbs (1989a: 187) has stated: "Serious problems may arise in distinguishing between intentional and accidental bone damage, and even when damage is convincingly intentional, the actual intent may not be obvious." Easiest to identify in skeletal remains are lesions caused by edged weapons and Wenham (1989: 127) provided a summary of certain criteria to differentiate sharp force injury from other types of trauma and post-mortem damage. These comprise: (1) linearity of the injury, (2) well-defined and clean edges, (3) flat, smooth and sometimes polished cut surface and (4) parallel scratch marks on some cut surfaces. Probably one of the earliest accounts of cranial injuries caused by bladed weapons is reported from the early thirteenth century. Gerald of Wales, a churchman who attended the exhumation of bones at the monastery at Glastonbury thought to belong to King Arthur, observed the following lesions:

> "His skull was almost prodigiously or freakishly capacious and large, to the extent that the space between his eyebrows or eye sockets was easily a palm's breadth across. Ten or more wounds were visible in it, all of which except one, larger than the rest, which had made a great yawning gap and appeared to have been fatal, had completely healed over with a scar" (Pickles, 1999: 233).

Unhealed blunt cranial trauma can lead to the presence of either concentric or radiating fracture lines. The amount of force applied will dictate the extent and type of fracture. At best, only the outer table will become traumatised and a permanent indentation may remain. Severe trauma can lead to comminuted fractures where the bone is broken into more than two fragments. This might have considerable effects on the brain if the blow was directed to the skull; internal bleeding can produce haematoma, which may apply pressure on the brain, leading to death of brain tissue, paralysis and other complications. However, haematoma rarely become calcified and would therefore not appear in human skeletal samples (Miller and Jennett, 1968; Weber and Czarnetzki, 2001a). Equally, infections of a deep cranial wound can lead to meningitis and subsequent death. However, even superficial wounds might become infected with probably lethal outcome if septicaemia develops. Furthermore, countrecoup injuries to the brain have to be considered, where the velocity of the blow leads to lesions on the opposite side of impact, since forces tend to travel (Kissane, 1990; Roberts, 1991). However, brain damage can usually not be assessed in archaeological human remains. Even with medical care, 3-11 percent of depressed skull fractures are lethal (Miller and Jennett, 1968).

Healed blunt force injuries of the cranial vault are regularly found in skeletal samples; they might be only a few centimetres in diameter or rather large with the fracture lines still visible (Stirland, 1996; Lovell, 1997a). Postcranial injuries, from both sharp-edged weapons and blunt force, are less commonly reported. In the absence of typical polished edges, the presence of cut marks on long bones might be hard to evaluate and the classic 'butterfly' fracture of blunt force trauma, where a butterfly-shaped piece of bone becomes separated, can also occur in post-mortem changes (Ubelaker and Adams, 1995).

T. Anderson (1996) conducted a literature survey of weapon injuries during the Anglo-Saxon period. He identified 14 individuals with healed and unhealed cranial and postcranial trauma. All but one of these individuals were male, displaying cuts made by swords and one possible axe injury; one individual was probably female. Only four lesions showed evidence of healing, leaving a vast majority of unhealed weapon wounds (71.43 percent), although it cannot be assessed whether the cranial injuries were the ultimate cause of death or if some other lethal injuries were responsible.

3.5.3 Spondylolysis and spondylolisthesis

Aufderheide and Rodríguez-Martín (1998: 63) define spondylolysis as an "ossification union failure of the *pars interarticularis* of the vertebra, resulting in separation of the vertebra into two parts", although separation might occur at other elements of the neural arch, such as the pedicles or lamina. Spondylolisthesis is the more severe form, where the vertebral body slips forward on its immediate neighbour. The aetiology of spondylolysis has been discussed in a controversial manner over many years. A genetic origin was assumed by Stewart (1931), but this was later rejected by him (Stewart, 1953). Aufderheide and Rodríguez-Martín (1998) discuss spondylolysis/spondylolisthesis together with congenital disorders, whereas a stress-related origin was favoured by Jurmain (1999). Merbs (1983; 1989a; 1989b; 1996a;

1996b), who probably provided the most comprehensive study of spondylolysis, suggested that underlying developmental factors might be of importance. He concluded that the condition is usually the result of a fatigue fracture most commonly seen in young individuals. A positive correlation of spondylolysis and spina bifida occulta found in clinical studies argues for a congenital predisposition leading to the separation (Waldron, 1993). Spondylolysis is only present in the *Hominidae* and it is therefore linked to bipedalism (Merbs, 1996b). It is absent in children before they start to walk and has never been reported in the newborn, although two cases have been mentioned in the clinical literature, where spondylolysis occurred in children before walking age. In addition, it has not been reported in paralyzed patients, who are never able to walk (Merbs, 1989a). In the palaeopathological literature, there seems to be no unanimous opinion on the correlation of advancing age and spondylolysis frequencies. Merbs (1996b) suggested that lower rates seen in elderly individuals were due to some lesions having healed. Bridges (1989) observed an increase in frequency rates in older individuals, especially females, in a North American skeletal population from Alabama and suggested that age-related bone loss might play a role in a late onset for the disease. The clinical literature states an onset in childhood, 4-6 percent of children in the US at age six are affected, but before the age of four, it is rarely seen (Kissane, 1990).

Most commonly observed on the fifth lumbar vertebra (L5) or L4, other lumbar and thoracic vertebrae can also be affected. Spondylolysis may also occur on the sacrum (Merbs, 1996a). In a clinical context, frequencies for individual vertebrae vary, but are generally much higher for L5 (80 percent), with decreasing frequencies for L4 (15 percent), L3 (3 percent) and the remaining vertebrae (2 percent). In the clinical literature, multiple vertebral involvement is described as rare (Zilch and Weber, 1989).

Modern data suggests that 3-7 percent of the US population are affected and men are two to four times more likely to display the condition than women (Weinberg, 2000), although Aufderheide and Rodríguez-Martín (1998) reject a sex predilection, but stress that male prevalence is slightly higher. However, a number of researchers found higher frequencies, often of statistical significance, for males, linking higher mechanical loads on the male spine to their findings (e.g., Gunness-Hey, 1980; Merbs, 1983, 1995; Waldron, 1993; Trembly, 1995; Arriaza, 1997). The opposite was recorded for some Native American Indian groups. Reinhard and co-workers (1994) argued that demanding tasks such as hide scraping, house construction and the gathering of firewood were only undertaken by women, therefore exposing their lower spines to physical stress.

Commonly, in modern patients lesions occur bilaterally, but unilateral cases have been reported (Zilch and Weber, 1989). Waldron (1992a) found a prevalence of 9.3 percent of unilateral lesions in a large multi-period British sample (5 of 54 individuals with spondylolysis). With all types of spondylolysis, complications, such as backache, sciatic pain or neurological problems may occur. However, these symptoms are more common in individuals with spondylolisthesis, where the forward slipping of the affected vertebra can cause nerve impingement (Resnick and Niwayama, 1988; Apley and Solomon, 1990; Dandy and Edwards, 1998).

Today, microtrauma or stress fractures are made responsible for causing the separation of the neural arch and in some athletes rates as high as 62 percent have been reported (Weinberg, 2000). In contrast, typical population rates of 4-8 percent appear to be the norm (Aufderheide and Rodríguez-Martín, 1998). Hyperflexion and hyperextension of the lumbar spine are thought to be the cause of these stress fractures, although an underlying genetic predisposition is necessary for its onset (Roberts and Manchester, 1995). Many different types of activities and sports have been cited to trigger spondylolysis, e.g., gymnastics, javelin throwing, American football, weight lifting, dancing, contortionism, diving, hockey, rowing, canoeing, handball and cricket (Merbs, 1996a; 1996b) and it is tempting to relate observations of spondylolysis in skeletal remains to specific activities. Arriaza (1997), for example, linked the high prevalence of spondylolysis he observed in prehistoric inhabitants of Guam to heavy physical labour performed to move large stones. However, Merbs (1996b) warned against such a simplistic approach and the question remains as to what extent genetic or developmental predispositions might explain differences in archaeological population studies (Jurmain, 1999).

Among the Sadlermuit, a Canadian Inuit group, Merbs (1983) found a 63 percent prevalence (44 of 70 vertebral columns). Including observations of partial separation, a sample of multiple Inuit populations had a prevalence of approximately 12.5 percent (51 cases in ca. 400 individuals), but rates for sacral spondylolysis alone were lower at 4 percent (16 of 373 individuals) (Merbs, 1995). Bridges (1989) found slightly higher frequencies in females (20 percent) than in males (17 percent) in a population of 157 individuals from northwestern Alabama. Modern studies on American Caucasians reported frequencies of less than 10 percent (Wiltse *et al.*, 1976), while Inuits showed rates between 20 and 40 percent (Merbs and Wilson, 1960; Lester and Shapiro, 1968). Stirland (1996) compared male individuals from a medieval cemetery sample from Norwich, Norfolk, with victims of the sinking of the Tudor warship *Mary Rose*, and found male prevalence rates for fifth lumbar vertebrae of 8.5 percent and 11.1 percent, respectively. The skeletons from the eighteenth to nineteenth-century crypt of Christ Church, Spitalfields, London had low frequencies of spondylolysis with 2.2 percent for males and 0.6 percent for females, respectively (Waldron, 1993). Lithuanian historic skeletal populations had slightly higher rates of lumbar spondylolysis (6.64 percent) with the defect usually occurring on the fifth lumbar vertebra. High frequencies (15.8 percent) were found in individuals with complete lumbarisation of S1 (Jankauskas, 1994). This is contrary to the observations made by Roche and Rowe (1951) who found a negative correlation between transitional lumbar vertebrae and spondylolysis in the Terry and Hamann-Todd collections.

Merbs (1989a) noted that modern individuals with spondylolysis in the United States had higher bone mineral values, while low values were correlated with vertebral compression fractures, hypothesizing that the same vertical forces might be at work, producing different fractures according to the level of bone mineral. Despite this extensive research, it is still debated whether variations in activity levels alone or in combination with genetic and developmental factors cause spondylolysis (Jurmain, 1999). This is especially puzzling, because some agreement on a multi-factorial origin had been reached in the 1990s (Roberts and Manchester, 1995).

3.6 Infectious Disease

A huge variety of different conditions can be discussed under the subject of infectious disease (Inhorn and Brown, 1990). Infection is defined as the successful establishment of a pathogen inside a host's body. Bacteria, viruses, fungi and parasites are all pathogens that are able to cause disease but, ultimately, signs and symptoms of a specific disease will not develop in all cases of pathogen infiltration (Riede and Schaefer, 1999). The manifestation of infectious disease will largely depend on the host's immune status. However, a person's immune system is dependent on sex, age, nutrition and the presence of other diseases already afflicting the host. Other factors which influence the development and course of infectious diseases comprise the virulence of the pathogen, population density, hygiene, housing and environmental conditions (Ortner, 1998; 2001). The body's usual response to infection is inflammation, which manifest itself in four signs described as early as the first century AD by Celsus, a Roman medical writer, as *rubor*, *calor*, *tumor* and *dolor*, (redness, heat, swelling, and pain) (Pschyrembel, 1982; Kollesch and Nickel, 1994). In case the immune system of the infected person is compromised or the virulence of the pathogen is high, death will occur shortly after infiltration. In such a situation, the time span between infection and death is usually too short to enable any responses of skeletal tissues. Ten days to three weeks are the minimum survival time after which bone reaction can be expected, although this time span can increase considerably with advanced age and low nutritional status of the infected host (Rühli and Böni, 2001). Therefore, a certain amount of time needs to be survived by the patient and only chronic infection usually leads to changes in the skeletal system. Acute infections are either survived or they kill the person before skeletal changes become manifest; the latter is usually assumed for past populations (Wood *et al.*, 1992). There are several hundred different infectious diseases described in the clinical literature (e.g., Schreiber and Mathys, 1988) but unfortunately for the palaeopathologist, bone tissue reacts to different infections in a similar way and it is usually not possible to achieve a more detailed diagnosis.

Infectious diseases are separated into two main categories: specific and non-specific; while in the first a specific pathogen is known to cause the disease, in the latter a number of pathogens may have caused inflammation (Merbs, 1992; Roberts and Manchester, 1995). Examples of specific infectious agents and the infections they are responsible for are *Mycobacterium leprae* (leprosy), *Mycobacterium tuberculosis* and *Mycobacterium bovis* (tuberculosis), *Yersinia pestis* (plague) and *Treponema pallidum* (yaws, endemic and venereal syphilis). One of the most versatile non-specific pathogens belongs to the *Staphylococcus* group. Their toxic waste products can lead to septicaemia, abscess and toxic shock syndrome, to name only a few (Riede and Schaefer, 1999). In general, women are found to have a better immune response to infectious diseases than men and children (Stini, 1985; Ortner, 1998). This is obviously related to an evolutional buffering system helping women to combat the increased risk of infection during pregnancy and childbirth. However, this is not true for all forms of infections; for example, urocystitis (infections of the urethra) and cystitis (inflammation of the bladder) are much more prevalent in women (Riede and Schaefer, 1999). In the past, the biological advantages women had in warding off most pathogens might have been counteracted by cultural systems favouring male off-springs and adult men by giving them preferential access to better quality food, therefore preventing malnutrition or undernutrition, which are known to compromise the immune system (Stinson, 1985). Although women benefit from an enhanced immune reactivity, this also leaves them more susceptible to auto-immune diseases (Cannon and St. Pierre, 1997).

3.6.1 Non-specific infections (NSI)

Non-specific infection of bone is divided into three subcategories according to which part of the bone tissue is affected: (1) periostitis, which is an inflammation of the periosteum, or the thin membrane tissue covering a bone's surface, (2) osteomyelitis, is an inflammation of the bone marrow, and (3) osteitis, entails inflammation of the bone cortex. Periostitis is the most commonly observed non-specific infection seen in archaeological skeletal remains. Usually periostitis can be caused by infectious agents such as *Staphylococcus aureus* – in fact, 90 percent of all modern infections are caused by this bacterium (Schultz, 1986), but periostitis can also develop as a response to trauma, chronic venous insufficiency (Resnick and Niwayama, 1988) or subcutaneous bleeding, for example in the metabolic condition called scurvy (vitamin C deficiency) (Stuart-Macadam, 1989). While the first cause (infectious agents) is an infectious response, the remaining causative factors are of aseptic origin, meaning they have no true infectious basis. It has to remain speculation which infectious agent was responsible in antiquity. Today, the *Staphylococcus* group, and among them, especially *Staphylococcus aureus*, live on skin and mucous membranes and approximately 15 to 40 percent of otherwise healthy humans are carriers who can potentially infect themselves or transmit the bacilli to other individuals (Kissane, 1990). However, other potentially harmful bacteria, such as *Escherichia coli*, *Salmonella typhi* and *Neisseria gonorrhoeae*, live in close proximity with, and even within, humans (Riede and Schaefer, 1999). Infection can result directly from a wound or infected soft tissue (e.g., middle ear infection (otitis media) and tonsillitis) or it can be spread by other means through the body. In haematogenous osteomyelitis, for example, bacteria are transported via the bloodstream from an affected area to some other part of the human body. Osteomyelitis can begin as an infection of periosteum (periostitis) and, if untreated, eventually can lead to involvement of bone cortices (osteitis). Occasionally, chronic infection results in the penetration of the bone cortex and the pathogen then enters the medullary cavity, although a more common cause of medullary infection is through the introduction of bacteria via the bone's own arterial system. Once established in the medullary cavity, a site of infection (gumma) forms which, over a number of years, gives rise to a suppurative (pus forming) condition at the site of infection, termed osteomyelitis. Necrotic destruction of the cortex follows and this necrotic bone particle (sequestrum) is expelled from the bones' interior via a draining sinus (cloaca) through which also the pus drains. These cloacae are usually accompanied by surrounding areas of woven new bone and other small, rarefied foci of cortical destruction formed within a new layer or sheath of bone (involucrum) surrounding the original bone surface. The presence of a cloaca in dry bone is a distinctive diagnostic feature of osteomyelitis (Ortner and Putschar, 1985). However, several forms of osteomyelitis are known today and not all proceed to develop the same features. One example is a non-suppurative form of osteomyelitis that is known as Garré's chronic sclerosing osteomyelitis. It is most often seen in the mandible of children and younger adults, with a slight predilection for the female sex and "changes appear as supracortical but subperiosteal proliferation of reactive new bone with prominent osteoblastic rimming" (Kissane, 1990: 1113).

Periostitis and osteitis can be regarded as primary and secondary stages in the onset of osteomyelitis (Steinbock, 1976). While identifiable in dry bone, they only indicate that the individual died before the onset of the next stage. Periostitis and osteitis are medically not accurate terms, because they describe one phase in an increasingly severe pathological continuum. On the other hand, untreated periostitis might not develop into osteomyelitis. Therefore, periostitis and osteitis may indicate only the presence of an infectious condition *per se*. Lesion categorisation is a constant dilemma in the diagnosis and interpretation of disease when using only skeletal tissue (Webb, 1995). A comparative study of modern medical data on infectious disease is hampered because radiographs are usually not part of modern diagnostic methods since changes to the periosteum are rarely visible on radiographic films. Furthermore, rapid treatment of the modern patient is essential and normally achieved by antibiotics. Consequently, many of the subtle osseous changes observable on archaeological bone are rarely identified as part of the diagnostic process in living human beings.

However, periosteal new bone formation may not be non-specific after all, as it can also result from treponemal infection, which is caused by a specific bacterium – the spirochete *Treponema pallidum*, which can lead to venereal syphilis. However, in the early stages of the condition a reliable differentiation is hardly possible and only tertiary treponemal disease produces distinctive cranial lesions such as stellate scars (*caries sicca*) (Ortner and Putschar, 1985; Rogers and Waldron, 1989).

In British archaeological skeletal remains dating from the Neolithic to the Anglo-Saxon period, periosteal new bone formation rates are highest on the tibiae and fibulae (Brothwell, 1981), and several circumstances leading to this finding have been discussed in the palaeopathological literature. The likelihood of continuous blows to, and bruising of, the lower legs, encountered as a natural part of living in an agricultural society have been cited by Roberts and Manchester (1995). This might be one explanation but, in all long bones, the tibia is also the most commonly affected in syphilitic or treponemal infections (Webb, 1995). Additionally, varicose veins and venous stasis with subsequent ulceration have been thought to be causative factors, although even more inspired speculations have been added to the discussion. For example, Harman (1990) proposed that periostitis of the tibiae and fibulae observed on several male individuals from the Anglo-Saxon site of Apple Down were due to the wearing of leggings, which were not regularly changed. A more generalized concept was approached by Goodman and co-workers (1988) who listed tibial periostitis among other features of skeletal stress indicative of poor population health. This approach is justified by the synergistic relationship between malnutrition and the occurrence of infectious diseases (Goodman *et al.*, 1984b).

While periostitis itself is rarely life threatening, osteomyelitis can lead to serious consequences, and septicaemia in the pre-antibiotic age might have been responsible for many deaths. Even in cases where the individual showed signs of healed lesions and has obviously survived for a considerable amount of time, pathogens might lie dormant, waiting for more favourable conditions, e.g., a suppression in the host's immune system, to become active again (Zilch and Weber, 1989). Modern clinical data indicate that two particular age groups are especially at risk of succumbing to infectious diseases. Young children have a higher risk of developing tuberculosis, for example. Tuberculosis is one of the major infections in children worldwide and leads to considerable morbidity and mortality. This is linked to factors such as overcrowding, poverty and the HIV pandemic (AIDS in Europe Study Group, 1996; Walls and Shingadia, 2004). Next to respiratory diseases, gastrointestinal infections are more prevalent in children than adults. They contribute to a high childhood morbidity and mortality, especially in developing countries. Diarrhoea caused by *Escherichia coli* is responsible for an estimated death of 380,000 children annually (Steinsland *et al.*, 2003). In the elderly, the decline in immunity contributes to the increasing risk and severity in infectious disease (Rafi *et al.*, 2003). With reference to non-specific infection of bone tissue children are more susceptible because their bones contain more blood vessels that are responsible for supplying the areas of bone growth. With the oxygen transported through the blood, pathogens can easily reach these regions and in the presence of iron, which also becomes distributed through the bloodstream, these pathogens can thrive (Ulijaszek, 1990). Periosteal reactions are usually more severe in children because of the periosteum's anatomy. The periosteum consists of two layers; the innermost or osteogenic layer contains a dense network of elastic fibres, blood vessels and bone cells, while the outer fibrous layer is composed of dense connective tissue containing blood and lymphatic vessels, as well as nerves (Tortora and Grabowski, 1996). These two layers are important for growth, repair and nutrition of bone. In children the periosteum is more susceptible to haemorrhage and separation from the cortex by infection or trauma, because the anchoring fibres, Sharpey's fibres, which bind the periosteum to the bone cortex are less numerous (Kissane, 1990).

3.6.2 Chronic maxillary sinusitis

The paranasal sinuses comprise of frontal, ethmoid, sphenoid and the largest, maxillary sinuses, all of which are connected via the nasal cavity (Tortora and Grabowski, 1996). They function as the body's first line of defence against pathogens infiltrating the human body through the airways (Roberts *et al.*, 1998). The interior of each sinus is covered with a sticky mucosal lining which is able to prevent pathogens and small particles from reaching the lungs. Tiny pulsating hairs – the cilia – transport the mucus-trapped material into the back of the nasal cavity from where it is swallowed (Kissane, 1990). Any of the sinuses can potentially be infected but, due to their anatomy, the maxillary sinuses are especially prone. Only one opening located high up in the sinus – the ostium – connects with the nasal cavity. If blockage of the ostium occurs, or the cilia become immobilized, mucus can accumulate at the floor of the sinus – providing an excellent breeding ground for bacteria causing inflammation (Riede and Schaefer, 1999). Infection of the maxillary sinuses is a common medical condition affecting a large proportion of today's population and is especially common in younger children, in whom it complicates between five to ten percent of all upper respiratory tract infections (Ong and Tan, 2002). Several factors can lead to the development of sinus inflammation. These include poor air quality, upper respiratory tract infections, specific infectious diseases such as leprosy and tuberculosis, allergies and certain types of dental disease such as periapical abscesses (Roberts *et al.*, 1998). Infection may spread from one sinus to the other or through the bloodstream from some other infected body tissue (Riede and Schaefer, 1999). Diagnosis in the living person is based on typical signs and symptoms – headaches and facial pains as well as a blocked nose in its acute stage, or after persisting for several weeks, purulent nasal discharge, chronic coughing and a sore throat, overall fatigue and an impaired immune system (Boocock *et al.*, 1995). This may lead to serious complications because bacteria can spread into the orbital tissues and meninges (Kissane, 1990). Here they can cause osteomyelitis, subperiosteal abscesses or meningitis (Riede and Schaefer, 1999)

Of interest to the palaeopathologist are the changes associated with chronic disease observable on the bone itself. In the clinical literature, dry bone changes in maxillary sinusitis are rarely reported. This is due to modern diagnostic criteria – usually by radiography – where fluid levels within the sinuses are evaluated and bone changes are not one of the diagnostic criteria (Nishimura and Iizuka, 2002). However, a number of researchers have mentioned bone involvement in patients with chronic maxillary sinusitis and animal experiments have shown that bone formation and/or resorption may occur (Lewis *et al.*, 1995).

While non-specific infections affecting other parts of the human skeleton are frequently mentioned in the palaeopathological literature, studies focusing on maxillary sinusitis in skeletal populations are relatively rare. Wells (1977) was probably the first researcher who analysed maxillary sinusitis in a systematic way, and some other studies on large samples followed (Merrett and Pfeiffer, 2000). However, individual cases of skeletons with signs of sinusitis are reported on occasionally but rarely in a systematic populations-based study (e.g., Hawkes and Wells, 1983). There may be two reasons for this – firstly, in undamaged skulls the sinuses are not readily observable and endoscopic examination would require invasive drilling into the bone, a procedure not always accepted by curators of skeletal collections, and secondly, the interaction between maxillary sinus infection, bone response and causative factors is as yet ill understood.

3.6.3 Rib periostitis

Clinical diagnostic criteria of tuberculosis of the bones have helped to identify tuberculosis in historic and prehistoric remains, both human and non-human. Since the 1980s, a new diagnostic criterion for tuberculosis seen in dry bone specimens has been added to this list. Kelley and Micozzi (1984) have suggested that new bone formation on the visceral aspect of ribs may result from chronic pulmonary infection. More recently, Eyler and co-workers (1996) have correlated radiologically documented rib enlargement with tuberculosis, and one assumes this equates to new bone formation on this skeletal element. In both publications, the conclusion was reached that costal new bone formation may be associated with pulmonary tuberculosis.

Despite its antiquity and likely contribution to numerous deaths, tuberculosis is rarely reported in archaeological human remains (Roberts *et al.*, 1994). Several factors are made responsible for this apparent scarcity: only a small percentage of individuals suffering from tuberculosis actually develop skeletal changes that can be identified by the palaeopathologist, individuals may have died from the disease before they could develop bone lesions, or tuberculosis was not as common after all. However, the inadequacy of diagnostic criteria for detecting tuberculosis in dry bones has to be considered (Roberts and Manchester, 1995). Several studies have tried to establish tuberculosis as the cause of new bone formation on visceral rib surfaces, both in a modern and archaeological context (Kelley and Micozzi, 1984; Molto, 1990; Pfeiffer, 1991; Kelley *et al.*, 1994; Roberts *et al.*, 1994; Sledzik and Bellantoni, 1994; Roberts, 1999; Santos and Roberts, 2001). However, the correlation of new bone formation seen on visceral surfaces of ribs with pulmonary tuberculosis has been questioned lately. Even in individuals with confirmed tuberculosis, rib periostitis could have resulted from a secondary infectious disease such as pleurisy, chronic bronchitis, metastatic carcinoma, osteomyelitis and treponemal disease (Roberts, 1999). Ultimately, the presence of new bone formation on visceral rib surfaces may indicate a tuberculous infection but, since definitive evidence is absent, it may be safer to restrict diagnostic criteria for tuberculosis to the classic lesions of Pott's disease and consider the described rib changes as an indicator of potentially many chronic pulmonary diseases (Santos and Roberts, 2001).

3.6.4 Endocranial lesions

Endocranial new bone formation in archaeological skeletal material has been a relatively recent observation and research has been largely restricted to non-adults (e.g., Schultz, 1987; 2000). Lesions can occur in different forms, either as new bone laid down on the endocranial table, as an expansion of the inner table or as capillary vessel impressions. The latter are commonly seen on the occipital bone around the cruciate eminence, but they can also appear on the frontal and parietal bones near the venous drainage systems. Endocranial lesion variability suggests that different aetiologies have to be considered and there are many suggestions as to what may have caused them. For example, tuberculosis, meningitis, epidural haematomas, birth trauma, scurvy, neoplastic disease and venous drainage problems can all lead to haemorrhage or inflammation (Kreutz *et al.*, 2000; Wapler and Schultz, 2000). However, in very young children normal growth can manifest itself as woven immature new bone formation on the endocranium (Williams and Warwick, 1980) but histological analysis may be helpful in establishing a differential diagnosis (Schultz, 2001).

3.7 CONGENITAL AND DEVELOPMENTAL ANOMALIES

Congenital anomalies occur during intrauterine development of the foetus. Anomalies might be acquired or inherited; they can be present at birth or only detected several years later. The aetiology of many of these anomalies is not well understood, but in industrialised countries 90 percent are due to a mix of genetic disturbances and environmental causes, and approximately 40 percent are manifest on the skeleton (Aufderheide and Rodríguez-Martín, 1998). The genetic background of many of these malformations is complex; only one-third of them are caused by single gene disorders and even less (8.3 percent) by chromosomal alterations. The remaining changes are initiated by multi-factorial gene disorders (Barnes, 1994). Three modes are responsible for congenital disease development (Medical Research Council Vitamin Study Group, 1991):

a) mutagenic, with the foetus inheriting a gene defect or chromosomal anomaly through their affected family or through a new mutation;
b) at conception, including most non-inherited chromosomal anomalies;
c) teratogenic, where postconception some agent has non-inheritable effects.

Non-inheritable effects that might affect the foetus in its intrauterine environment include bacterial and viral maternal infections such as rubella (German measles), chicken pox and shingles, exposure to toxins (e.g., maternal smoking and alcohol consumption), drugs, radiation, maternal malnutrition and trauma to the foetus. All of these have been associated with malformations, although their exact contribution is still unclear. Medical classifications differentiate between total failure of development, partial development, over-development, or abnormal development of parts of the body; although this might be over-simplistic, it is a practical way of applying some form of order to the multitude of congenital conditions (Roberts and Manchester, 1995).

In today's populations congenital anomalies are present in 4-5 percent of all newborns and 40 percent will die in the perinatal period (Aufderheide and Rodríguez-Martín, 1998). In Britain, congenital anomalies were first reported on a national basis in 1964 (Charlton and Murphy, 1997). In England and Wales about 5 percent of all babies are born with a congenital anomaly or other developmental defects. In 1991, a quarter of all deaths to children under the age of one were attributed to congenital anomalies (Botting, 1995). However, frequencies in different countries might vary considerably and comparisons between them might be severely hampered. Narchi and Kulayat (1997) studied congenital anomalies in more than 18,000 live births in a Saudi Arabian hospital They found an incidence of 3.71 percent of anomalies per 100 births, of which 9.6 percent affected the skeletal system. Although the intermarriage rate in the study population was very high (70 percent), they found no difference in congenital anomaly prevalence compared with other parts of the world. However, it has to be remembered that comparisons between populations might not always be feasible. More reasons why population variance might occur have been listed by Turkel (1989): (1) in poorer populations malnutrition and infectious disease are considered more important, (2) the health system does not cover the entire population, (3) statistics might not be in use in some countries, (4) differences in recording, definition and diagnosis. Furthermore, minor defects may remain undetected because they do not lead to signs and symptoms. In addition, regional fluctuation in environmental factors such as pollution and chemical contamination might play a crucial role in population differences. Population studies of congenital anomalies in archaeological human samples are equally hard to assess for the following reasons: severe anomalies often lead to spontaneous abortion and small foetal bones are less likely to survive diagenetic processes. If the foetus survives until birth, the malformed neonate might be subjected to neglect or active elimination followed by burial outside the common burial ground. These human remains would normally not appear in the archaeological record. Furthermore, some anomalies such as cleft palate are located on very fragile skeletal elements and therefore have a reduced chance to appear in poorly preserved skeletal samples. Less severe forms of anomalies are frequently found in skeletal samples and they are usually listed in archaeological reports, although their significance is rarely understood. There also appears to be some uncertainty about whether certain features such as some manifestations of spina bifida should be classified among the congenital anomalies or simply as a non-metric traits (Webb, 1995). However, a clear distinction might not be possible since the term 'anomaly' usually implies adverse symptoms for its bearer and this cannot always be inferred by the skeletal evidence alone. Some researchers have used specific anomalies to assume family relationships between individual skeletons or inbreeding within entire populations, ignoring the fact that some anomalies might also be caused by additional factors. For example, Campillo and Rodríguez-Martín (1994) implied a high degree of inbreeding judged by the high prevalence of spinal anomalies found in the Guanche population of the Spanish island of Tenerife.

3.7.1 Congenital anomalies of the spine (other than spina bifida occulta)

Most developmental anomalies of the spine are of no pathological importance. Commonly observed in palaeopathological studies are transitional vertebrae where a vertebra of one functional type assumes the form of its neighbour, e.g., the last thoracic vertebra T12 resembles the first lumbar vertebra, or the last lumbar vertebra assumes the form and function of the first sacral segment S1. Other types of spinal anomalies affect the intervertebral discs – sometimes they fail to develop at all and two (or more) vertebral bodies do not differentiate, forming a solitary body or so-called block vertebra. This occurs more often in the cervical vertebral column, but can appear at any spinal level. Additional ribs, either on the seventh cervical vertebra (cervical rib) or the first lumbar (lumbar rib), can lead to nerve impingement but usually their size is diminished and they do not impair normal body movement (Denninger, 1931; Black and Scheuer, 1994). Other vertebral anomalies like 'butterfly vertebrae' and 'half vertebrae' refer to forms of segmentation failures during foetal development. Transitional vertebrae at the lumbo-sacral level can develop two different features – in the case of sacralisation L5 fuses to the superior aspect of the sacrum leaving only four instead of five free lumbar vertebrae behind. In the opposite case – lumbarisation – the first sacral segment does not fuse to the other sacral elements but appears as a sixth free lumbar vertebrae, reducing the number of sacral segments to four. Occasionally, fusion occurs only on one side of the vertebra with possible pathological consequences leading to degenerative changes of the vertebral joints because of non-physiological torsions (Zilch and Weber, 1989).

According to the direction in which the transition occurred, cranial and caudal forms of transitional vertebrae are differentiated (Barnes, 1994). However, it is often difficult to assess the number of vertebrae present, especially when a reduction in vertebral elements took place, since their absence could have been caused by loss during or after excavation and not due to congenital absence. An increase in numbers is much more common, and "a strong genetic tendency for shifting … in either cranial or caudal direction" was noticed by Barnes (1994: 80). Caudal shifting is more prevalent than cranial shifts, but frequencies vary among populations. However, females have more cranial border shifting than males (Barnes, 1994).

Population differences of transitional vertebrae have been documented and frequencies of 3-5 percent are mentioned with two-thirds of all defects occurring as sacralisation (Aufderheide and Rodríguez-Martín, 1998). High rates for both conditions have been found for the Guanche population of Tenerife (Canary Islands, Spain); L5 sacralisation occurred in 6.28 percent, while S1 lumbarisation was prevalent in 5.44 percent of all observed individuals. Sacralisation was equally common in males and females. However, lumbarisation appeared much more often in females (9.3 percent) than males (1.7 percent) (Campillo and Rodríguez-Martín, 1994).

3.7.2 Spina bifida occulta (SBO)

Spina bifida has been documented and described in the early medical literature of the late nineteenth century. Generally defined as an incomplete midline fusion of one or more vertebral neural arches, clinically spina bifida occurs most often in the lumbo-sacral region (Zilch and Weber, 1989), while in archaeological skeletal samples the sacrum is more often involved (Ortner and Putschar, 1985). Two types of the defect have been recognized – the more severe form spina bifida cystica (or aperta), and the usually symptomless spina bifida occulta (SBO). The aetiology for both forms is the same: mechanical or metabolic intrauterine insults, infectious and deficiency diseases as well as exogenous toxins are all thought to influence the occurrence of spina bifida (Zilch and Weber, 1989). Furthermore, geographical, ethnological and social factors might play an additional role. Damage within the first four foetal weeks results in the open variant; after the fourth week, the occult form is found (Zilch and Weber, 1989). The cystic variant of spina bifida where the meninges, nerve roots or parts of the spinal chord extrude through the lesion are thought to be incompatible with life in the absence of medical intervention and it is highly unlikely to find evidence of this disease in the archaeological record. Assuming that some individuals might have survived for a certain amount of time, and providing they were subject to the same treatment after death as the non-afflicted part of the population, the disease should be found in skeletal remains. However, spina bifida in archaeological remains is usually only diagnosed in adult individuals after union of the posterior sacral growth centres, and cases of spina bifida cystica might be missed because it cannot be detected in non-adult skeletal samples. Having accepted the lack of evidence for the severe form of the condition, one further problem has to be resolved. In the palaeopathological literature definitions of SBO vary widely, with some authors including only sacral defects occurring above the level of S4 (Buikstra and Ubelaker, 1994), while others define the condition occurring at any level (Aufderheide and Rodríguez-Martín, 1998). The defect is clinically irrelevant and mainly asymptomatic since in life it is bridged by cartilage or membrane. Age and sex might play a role in the observed variations of SBO prevalence in skeletal populations. Turkel (1989) describes a number of studies where frequencies vary between 3 percent and 100 percent and concludes that this might be due to differences in male and female skeletal maturation. Females mature faster and at an earlier age than males, and it is probably prudent to consider both sexes separately and by individual age categories when comparing skeletal prevalence of spina bifida. Turkel (1989) advises to include only individuals older than 35 years to allow for delayed fusion in some individuals. Normally, fusion occurs between the ages of 7-15 years (Schwartz, 1995).

Recently, Barnes (1994) has suggested that the term spina bifida occulta is wrongly applied to most cases identified in skeletal remains, since the observed changes are not caused by a neural tube defect, but by hypoplasia or aplasia of the posterior parts of a vertebra, simply resulting in clefting of the neural arch. As it is general practice in the palaeopathological literature to refer to these changes as spina bifida, meaning 'cleft arch', this term has been preferred here.

With the lack of any pathological consequence due to the mostly subclinical nature of the defect, the importance of spina bifida occulta probably lies in its relation to other defects of the vertebral column such as spondylolysis (see 3.5.3 Spondylolysis and spondylolisthesis). However, some individuals with SBO might have experienced signs and symptoms such as maldevelopment of the feet or legs, scoliosis, incontinence, localized swelling at the lower end of the back, sometimes accompanied by hypertrichosis (excessive growth of hair) and scarring (Post, 1966)

3.8 Metabolic disorders

The growth and maintenance of bone tissue is influenced by diet or, more precisely, by the deficiency or excess of certain vitamins and essential minerals. These affect bone metabolism by controlling osteoblastic formation and osteoclastic resorption. In a palaeopathological context, certain forms of anaemia, scurvy, rickets and osteoporosis, all of which leave more or less distinctive signs on bones, are the most commonly observed metabolic disorders. However, as there was no definite evidence for scurvy and vitamin D deficiency in non-adults (rickets) or adults (osteomalacia) in the study samples, these diseases will not be discussed here. Iron deficiency anaemia is not strictly a metabolic disease, although dietary deficiencies can be one of the underlying causes. Furthermore, iron deficiency anaemia is known to occur in patients suffering from scurvy and/or rickets (Ortner, 1999).

3.8.1 Iron deficiency anaemia (Cribra orbitalia)

Pitting of the outer table of the skull and expansion of the trabecular area (diploë) between the two tables, and pitting of the orbital roof, have both been described in the palaeopathological literature since the last quarter of the nineteenth century (Welcker, 1888). However, the meaning of these commonly observed skeletal alterations remained obscure, and a variety of causative factors were taken into consideration, with anaemia, and here especially iron deficiency anaemia caused by a diet deficient in iron and blood loss due to parasite infestation, being the most probable among them (Hengen, 1971). Only in the 1980s were these bone lesions linked to anaemia found in modern clinical contexts (Stuart-Macadam, 1985; 1987). Nevertheless, a multitude of different forms of anaemia exists, both of acquired and genetic origin. Anaemia is a clinical term incorporating a number of conditions in which the reduction of haemoglobin below normal is noticeable, endangering oxygen transport to essential organs such as the brain, heart, kidneys and liver (Riede and Schaefer, 1999). Today iron deficiency anaemia is the most common form of anaemia and an estimated five to six hundred million people are affected worldwide (Kissane, 1990). Clinical studies place children between six months and three years of age, as well as females and the elderly at greater risk (Tortora and Grabowski, 1996). Early childhood anaemia is caused by the depletion of natural iron stores acquired *in utero* and the reduction of iron levels in breast milk after the first six months of life (Saarinen, 1978). However, low weight and premature birth can deplete iron stores even below the age of six months (Schulman, 1957) and "iron deficiency in pregnancy impairs the iron status of the fetus and infant" (Bergmann *et al.*, 2002: 155). Before the age of twenty, red bone marrow, in which red blood cell production takes place, is located within all available marrow space (Kissane, 1990). If the body's iron stores are low, more iron needs to be produced and stored within the red marrow leading to an expansion of that marrow. This is thought to result in the typical expansion of the diploë and thinning of the cortex on both the skull vault and the orbital roofs, where lesions are termed porotic hyperostosis and cribra orbitalia, respectively. Both conditions do not represent a disease *per se*, but rather denote a morphological feature. Porotic lesions of the orbits and the cranial vault can occur also in the genetic forms of anaemia such as sickle-cell anaemia and thalassaemia. However, they include, among other features, postcranial lesions in the form of severe widening of the medullary cavity accompanied by thinning of the cortex (Ortner and Putschar, 1985). However, genetic anaemias are probably not of importance in the central and western parts of Europe because they are usually seen in populations where malaria is or was endemic. Today malaria is more common in tropical and subtropical countries but, in the marshland areas of nineteenth-century Britain, the mosquito acting as a vector would have found prime breeding grounds (Smith, 1956). Land clearance may lead to the development of marshes or wetlands, and temporary warmer weather conditions may have allowed the mosquito to survive in the early medieval period, when it was probably known as 'spring ill' (Cameron, 1993). While malaria does not leave traces on the skeleton, the affected individual may develop skeletal changes of anaemia, such as cribra orbitalia, and potentially DNA of the malaria parasite could be detected in skeletons with signs of anaemia (Roberts and Cox, 2003).

Porotic hyperostosis can also occur in other deficiency diseases such as rickets and scurvy and the presence of more than one condition in a single individual might complicate diagnosis. The relationship between porotic hyperostosis and cribra orbitalia has been subject to much controversy, nevertheless Virchow (1874) had already supposed that both were part of the same process. Today it is assumed that porotic hyperostosis indicates more severe or long-term anaemia (Stuart-Macadam, 1989). However, clinical studies have confirmed that severity of bone changes is not necessarily correlated with severity of the anaemic reaction (Stuart-Macadam, 1998).

In a modern context, women are frequently diagnosed with iron deficiency anaemia, which is caused by higher iron demands during pregnancy or lactation, but menstrual blood loss has also been identified as contributing to higher iron demands in females (Siegenthaler, 1980). Higher female mortality and decreased life expectancy have been attributed to women being chronically iron deficient because their higher demands could not be met by the diet (Bullough and Campell, 1980). This statement is hard to disprove in past populations. It is unlikely that bone marrow expansion will result in skeletal changes in adults, since large proportions of red bone marrow are replaced by fatty yellow marrow, which is not involved in red blood cell formation, and therefore marrow space is less restricted in adults. Adult long bones contain haematopoetic (red) marrow only in the proximal epiphysis of the humerus and femur (Rozsahegyi, 1986). In the light of this physiological fact, skeletal evidence of anaemia is confined to anaemic conditions experienced during childhood (Stuart-Macadam, 1998; Lewis, 2002). Regrettably, it is still not possible to reliably assign a sex to immature individuals; therefore, sex-related differences in anaemia patterns in children from archaeological populations cannot be investigated at the present time. Recently developed methods of biomolecular sex determination might be able to remedy this in the future (Saunders, 1992).

Currently, three main manifestations of anaemia are linked to skeletal changes: (1) iron-deficiency caused by the inadequate intake or absorption of iron as well as blood loss caused by internal bleeding, (2) megaloplastic anaemia, caused by a deficiency and/or inadequate intake of vitamin B_{12} and/or folic acid and (3) anaemia caused by chronic disease and infection, where the body is withholding its iron stores against pathogens. These different types might exist parallel to each other, and attributing a specific form of anaemia in a palaeopathological context might be difficult. Some researchers even regard any kind of diagnosis of anaemia or its differentiation from osteomyelitis and scurvy as impossible without the help of microscopic analysis (Götz, 1988; Schultz, 2001). However, histological analyses are often not possible in the light of bone conservation and, additionally, they are time-consuming and costly, and need technical experience, which makes them impractical for the analysis of large numbers of skeletons.

The human body's iron metabolism is very complex and not yet fully understood. A number of factors can enhance or reduce iron absorption from the diet, which takes place through the mucosal lining of the intestines. Two forms of iron – haeme and non-haeme iron are differentiated depending on their source (Trellisó Carreño, 1998). Haeme iron occurs in meat, fish, poultry and blood and is more readily absorbed than non-haeme iron, which is present in vegetables, nuts, legumes and dried fruit (Garrow and James, 1993). Absorption can be increased in case of low blood iron levels or decreased when iron stores are at an optimum. In general, children absorb more iron than adults, because of their higher demands for nutrients, and women absorb double the amount of males (Riede and Schaefer, 1999), especially pregnant or lactating women (Bashiri *et al.*, 2003). In today's industrialized countries, dietary induced iron deficiency anaemia is relatively rare, but it is prevalent in developing countries (Bergmann *et al.*, 2002). This is connected to starvation and malnutrition; in the absence of red meats, shellfish and green vegetables, the main sources for iron (Trellisó Carreño, 1998), not enough iron can be obtained from the diet. On the other hand, if there is an over-reliance on certain food items with high phytate contents, such as cereals, nuts and legumes, non-haeme iron absorption will be hindered. This can also happen in calcium-rich diets, especially in young children who are weaned on cow's or goat's milk, but can also be due to prolonged breast-feeding; chronic intestinal disease such as diarrhoea and vomiting have a detrimental effect on iron absorption (Riede and Schaefer, 1999). Calcium is the only haeme iron inhibitor, and as little as one glass of milk can severely affect iron intake (Garrow and James, 1993). On the contrary, ascorbic acid (vitamin C), fish and fermented vegetables such as sauerkraut will enhance the body's ability to absorb iron (Garrow and James, 1993; Stuart-Macadam, 1998). Pathologically induced blood loss due to stomach ulcers, tumours of the intestinal system and uterus, and haemorrhoids as well as infestation with certain parasites such as *Plasmodium falsiparum* (malaria) and hookworm can lead to reduced iron levels (Reinhard, 1992; Holland and O'Brien, 1997).

Iron is essential for a number of body functions, including the production of haemoglobin, the protein which is responsible for oxygen transport from the lungs to other tissues of the body and, in reverse, carbon dioxide back to the lungs (Tortora and Grabowski, 1996). Lovell (1997b: 115) lists several signs associated with iron deprivation; these include stunted growth, delayed maturation, decreased work performance and inactivity. Irreversible developmental defects may occur in children in the form of shortened attention span and diminished conceptual learning (Ryan, 1997). In contrast, increased iron levels can lead to cirrhosis of the liver or pancreas and diabetes mellitus (Riede and Schaefer, 1999) but they are also associated with an increased risk of developing cancer, because iron is utilized as a nutrient by tumour cells (Tortora and Grabowsky, 1996).

Deficiencies in vitamin B_{12} and folic acid, another member of the vitamin B complex, are classified as megaloblastic anaemia. Folic acid sources, like iron sources, are found in liver and leafy green vegetables. However, vitamin B_{12} is the only B vitamin not present in vegetables but found in liver, kidney, milk, eggs, cheese and meat. Neural tube defects in neonates are associated with folic acid deficient mothers, whereas a lack of vitamin B12 can cause severe neurological problems such as ataxia (lack of muscular coordination), memory loss, weakness, personality and mood changes and abnormal sensations. Additionally, osteoblast activity is impaired, compromising the bone's ability to maintain itself (Tortora and Grabowski, 1996). However, a recent clinical study has detected that maternal vitamin B_{12} deficiency, in conjunction with a lack of folic acid, might equally be responsible for neural tube defects in newborn babies (Suarez *et al.*, 2003).

Anaemia caused by chronic disease and infection, or ACD (anaemia of chronic disorders), is linked to the body's iron-withholding mechanism, a natural defence against pathogens such as bacteria, parasites and tumour cells. This mechanism leads to withdrawal of iron from the blood by storing it in bone marrow because starving these invaders of iron might prevent their successful proliferation (Jandl, 1991; Kent *et al.*, 1994; Marx, 2002). Many common infectious agents are damaged by this withholding mechanism, and the development of fever can participate in this. Iron-starvation decreases the incidence and intensity of infectious processes, while iron overload compromises the iron-withholding response and results in an increased incidence and virulence of infections caused by bacteria, fungi and protozoa (Kent *et al.*, 1994: Table 2). However, animal tests have confirmed that this is not necessarily the case for all tumour cells (Simonart *et al.*, 2003).

3.8.2 Osteoporosis

Bone is not only important as a supporting structure, it is also necessary for controlling calcium and phosphate exchange, the two minerals responsible for maintaining bone mass (Apley and Solomon, 1990). Osteoporosis is a condition characterized by a reduced mass of bone, caused by bone resorption outweighing build-up of bone mass, with a consequent decrease in the physical strength of the skeleton and an increased susceptibility to fractures; however, bone quality is not altered (Siegenthaler, 1980). Literally, osteoporosis means 'porous bone' (from Greek 'osteo' meaning bone and 'poros' meaning 'little hole') and the term has been in use for one and a half centuries, although it referred to a wide variety of conditions. Only recently has osteoporosis been used to describe age-related bone loss (Brickley, 2002). It is primarily a disease of elderly women and, in Britain and other industrialized countries, it is the most commonly observed bone disease and a growing health problem with the extension of life expectancy. The primary cause in elderly women is the decline in ovarian function which accompanies the menopause (Roberts and Wakely, 1992). However, this process starts much earlier with approximately 1 percent of bone mass lost every year, beginning in the fourth decade of life, when peak bone mass has been reached (Riede and Schaefer, 1999). Apart from age, a number of extrinsic factors might be important. Sedentary habits, cigarette smoking, and some characteristics of modern lifestyles such as low calcium intake and alcohol consumption, as well as vitamin D deficiency, also seem to play a part (Kissane, 1990; Garrow and James, 1993). In clinical medicine, two forms of osteoporosis are differentiated – primary and secondary – with primary osteoporosis being the more common with 95 percent belonging to this type (Riede and Schaefer, 1999). Primary osteoporosis occurs mainly in postmenopausal women due to the reduction in bone mass induced by decreased oestrogen production. However, men are not entirely spared from this process but, as male individuals tend to have a higher peak bone mass, subsequent loss is less marked (Stini, 1990). Bone is formed during the growth period and is related to the intake of calcium and physical activity to maintain a healthy bone cell turnover. Other primary forms of osteoporosis comprise juvenile, pre-senile and senile types (Riede and Schaefer, 1999). The much less common secondary forms can be caused by inactivity over a certain time period. For example, increased bone-mass loss was noted in astronauts living in weightless conditions in space. Certain diseases and conditions such as diabetes mellitus, hepatic diseases caused by alcoholism, increased or reduced production of thyroid hormones (hyperparathyroidism, hypoparathyroidism), and starvation might lead to an increase in bone mass reduction (Kissane, 1990). Today the two most common forms of osteoporosis are postmenopausal, or type I osteoporosis affecting females and senile males, or type II osteoporosis found in both sexes (Riggs and Melton, 1983). Type I osteoporosis results in distal radius and vertebral fractures in women, while type II osteoporosis is more associated with femoral neck and vertebral fractures in both sexes (Aufderheide and Rodríguez-Martín, 1998). Risk factors for developing osteoporosis include ethnicity (Caucasoid or Asian), a positive family history, lean build and short stature, low calcium intake, inactivity, alcohol consumption and smoking, gastric or small bowel disease, liver disease, starvation and pregnancy (Kissane, 1990). Furthermore, other metabolic diseases such as scurvy, rickets and anaemia may influence the body's intake of calcium in a negative way, leading to a reduction in bone mass (Brickley, 2000).

In an archaeological context, osteoporosis may reflect poor-quality food in childhood, which leads to decreased bone mass. It may also indicate lack of physical exercise or advanced age. Furthermore, inferences about physiology, nutrition, lifestyle, sex, and associated behaviour are often made in palaeopathological studies (Weaver, 1998). While osteoporosis has been diagnosed on the basis of low bone weight alone (e.g., Boylston *et al.*, 1998), this may be the result of taphonomic factors such as modifications due to water and soil infiltration, plant roots and fungi growing within bones, or preparation techniques in the laboratory, and unusually light bones are therefore not a reliable indicator of osteoporosis (Schultz, 1997). Ultimately, only microscopic imaging can detect bone loss caused by the condition. A variety of relatively new medical imaging techniques, for example, single proton absorptiometry, dual energy X-ray absorptiometry (DEXA) or optical densiometry are available to assess the loss of bone mineral density found in osteoporosis (Hammerl, 1994; Brickley, 2000). However, in the absence of these diagnostic tools specific fractures can at least hint at the presence of reduced bone mass. Skeletal elements with high trabecular content are especially prone to fracture. Femoral neck fracture, Colles' fracture (fracture of the distal radius with posterior displacement of the distal end) and vertebral body fractures caused by a reduction of the horizontal trabeculae and subsequent collapse of the body, in combination with advanced age and female sex may all contribute to a diagnosis of osteoporosis (Brickley, 2000). Individuals with osteoporosis have a seven to ten-fold increase in fracture risk compared to healthy individuals and in the UK ca. 60,000 hip fractures, 50,000 wrist fractures and 40,000 vertebral fractures are clinically diagnosed annually, in which osteoporosis plays a vital role (Bell, 1997). Spinal fractures might result in a pronounced anterior curvature (kyphosis) or 'dowager's hump' and are the earliest signs of underlying osteoporosis (Garrow and James, 1993; Aufderheide and Rodríguez-Martín, 1998). Nevertheless, even severe osteoporosis does not always result in vertebral collapse (Roberts and Wakely, 1992), and therefore, the true rate of this disease is probably greatly underestimated when using macroscopic examination alone.

After having provided background information on indicators of health and disease used to assess the study samples, Chapter Four will detail information on the individual populations, as well as the methods used to analyse the material.

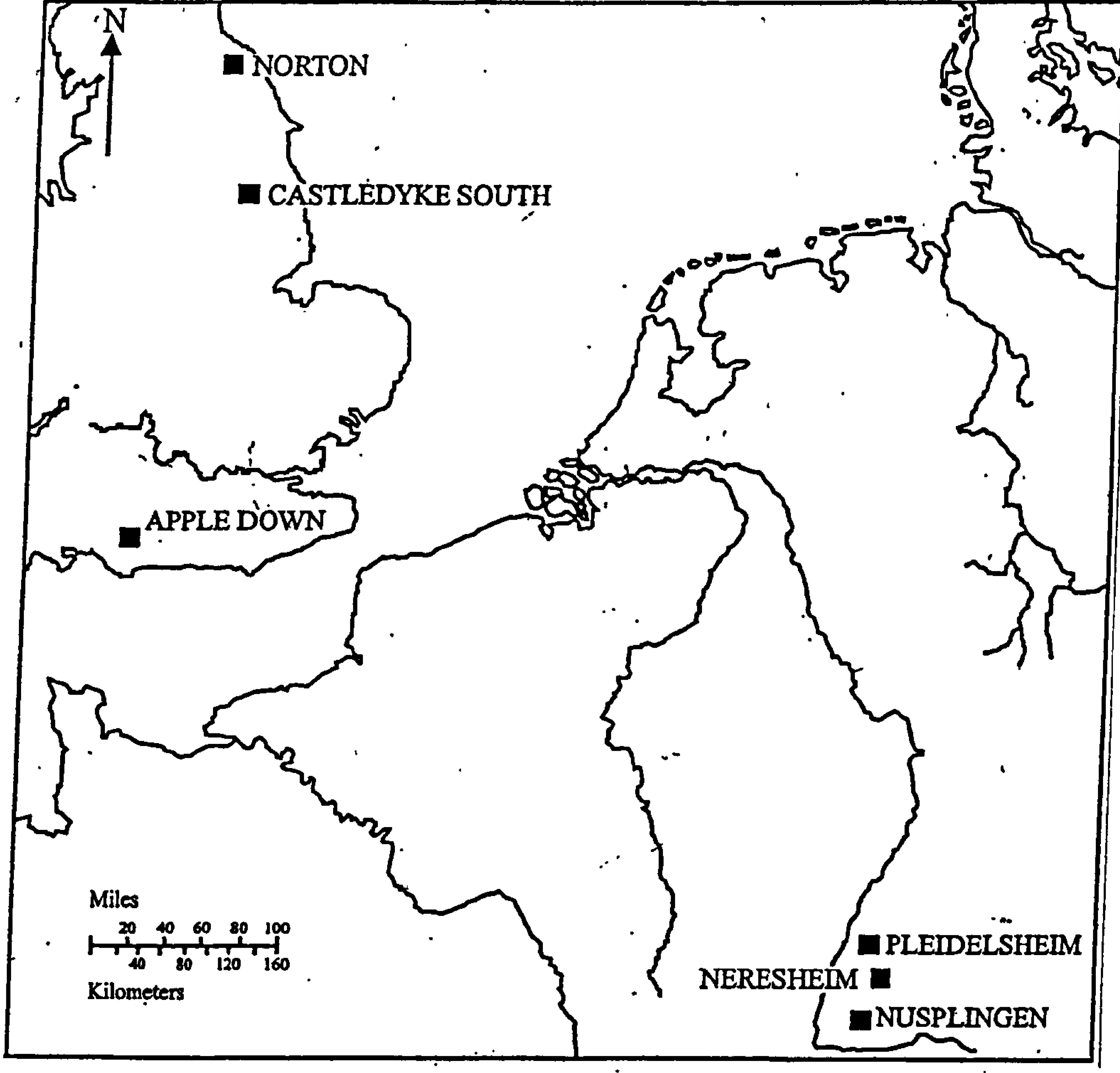
CHAPTER FOUR

MATERIAL AND METHODS

This chapter is subdivided into two parts. In the first section an introduction to the six skeletal samples is given, which summarizes the archaeological evidence and gives a short description of the different geographic locations and excavation history. In the second part, individual methods used to estimate age-at-death for adults and non-adults, biological sex, stature and non-adult growth are listed. Furthermore, methods of recording preservation of individual skeletons, sex, age and stature estimation, as well as the diagnosis of pathological conditions are detailed. In addition, the methods of calculating disease prevalence are described, as are the statistical methods used to analyse the results.

4.1 THE MATERIAL – AN INTRODUCTION TO THE STUDY SAMPLES

When skeletal human reports are compared, it becomes obvious that every individual funerary site has its own specific characteristics, not only in terms of location and topography, but also in the way the human remains were excavated and recorded. Equally, the post-excavational fate of the skeletal samples is of importance as all of these factors (and many more) can potentially influence the nature of study samples selected for analysis. The six samples described here are listed in alphabetical order within the two countries and not necessarily in the order they were analysed. The sites were chosen for the following reasons: skeletons had to be relatively well preserved and samples should consist of more than one hundred individuals to allow for statistical analysis. Furthermore, the human skeletal remains had to be accessible for study and some archaeological information needed to be present to evaluate the individual sites.



Map 1. Location of the six study samples.

4.1.1 *Apple Down (Compton, Chichester, West Sussex)*

The site of **Apple Down** lies on a slope of the South Downs in West Sussex and was the most southern British site used in the analysis (Map 1). With a height of 175 m OD, the view opens to the Sussex Downs in the north and the south, overlooking the coastal plain and the Isle of Wight. Between 1982 and 1987, the Chichester Excavation Unit excavated two cemeteries, after metal-detector discoveries in 1981. Cemetery 1 was a mixed-rite burial ground dated from approximately the early sixth to the late seventh century AD and yielded a total of 121 inhumations and 64 cremations. A further 74 cremations were inferred, but were not preserved due to extensive plough-damage. Cemetery 2 had been destroyed during the construction of a reservoir and only eleven graves could be recovered. The early Anglo-Saxon cemetery 1 is situated on the northern slope of a hill and, despite extensive trial trenching across the hilltop and field walking in the vicinity, any associated settlement remained undetected (Down and Welch, 1990). The initial excavation method consisted of stripping the overlying plough soil by hand. Grave structures cut into the underlying chalk were excavated in shallow layers. By 1984, time pressure made the use of a mechanical excavator to strip the topsoil unavoidable. A number of graves were found to be disturbed, and in seven graves no bones had survived. Graves were disturbed for a variety of reasons; most commonly, postholes dug to accommodate timber structures associated with cremation burials had cut into the graves, sometimes displacing bones.

The skeletal remains are currently curated at the Chichester District Museum, where they were available for study from November to December 2000. A total of 108 inhumed skeletons from Cemetery 1 were analysed as the burials from Cemetery 2 apparently do not belong to the early Anglo-Saxon period (Down and Welch, 1990). Likewise, the cremated human remains were not included in this study as alterations to human bone during the cremation process hamper palaeopathological observations. Nine individuals listed in the original skeletal report by M. Harman were not present at the storage facility in Chichester and could not be analysed. Although most of the skeletons were excellently preserved due to the chalk into which the graves were cut, chalky deposits were often not sufficiently removed by cleansing, especially from the dentition. The chalk's colour, which virtually resembled the colour of supragingival dental calculus, made calculus assessment difficult in some cases, but no attempt was made to remove these deposits. Furthermore, the high percentage of post-mortem breaks mainly on long bones was noted. It is not clear if this was caused during excavation or at a later stage. It has to be mentioned that the Apple Down skeletons up to the date of this study (2000) were only analysed for the original publication (Harman, 1990) and for a dissertation project (University of Southampton), during which it was necessary to transport the human remains by car from Chichester to Southampton.

4.1.2 *Castledyke South (Barton-on-Humber, South Humberside)*

The modern town of Barton-on-Humber is situated on the southern bank of the tidal estuary of the River Humber (Map 1). The first graves were discovered during the construction of an air raid shelter in 1939. Since 1975, several excavations and one watching brief were carried out by different organizations. This led to the recovery of human skeletal remains in 1982 and, in advance of redevelopment of the area, the Humberside Archaeological Unit recovered approximately 200 inhumations. Today, the burial ground lies on the southern margins of the town along the modern street of **Castledyke South** and is on the northern side of a low ridge at ca. 14.0-11.5 m OD overlooking the river. In the northern part of the excavated area the underlying ground consists of chalk, while the soil further south was sandy loam with inclusions of gravel and flint. Six discontinuous areas of more or less irregular size were cleared using mechanical tools and hand excavation, and it was assumed that only the eastern boundary – a prehistoric ditch – of the cemetery was identified. Analysis of the accompanying grave goods allowed subdivision of the cemetery use into several phases with the earliest inhumations dating to the late-fifth century and the latest to the late-seventh or early-eighth century AD. In the final publication, a total of 227 inhumations from 196 graves and one cremation burial were mentioned (Drinkall and Foreman, 1998).

In this current study 199 inhumations were considered, which are curated by the North Lincolnshire Museums Service (Scunthorpe). Since their storage facility was situated in a remote farm building lacking electricity, the Castledyke South skeletons were moved to the Department of Archaeology and Prehistory in Sheffield, where they were studied during the first two months of 2001. The majority (63 percent) of graves had been disturbed by later grave cuts or modern intrusions and this probably contributed to the skeletons being less complete than the sample from Apple Down. Nevertheless, dental remains were well preserved because of the alkaline soil. Until early 2001, the human remains from Castledyke South had only been studied by A. Boylston and co-workers (1998) for the original site report. Additionally, stereoscopic microscope investigation of the inner ear region was also part of a dissertation project (Dalby, 1994).

4.1.3 *Norton (Stockton-on-Tees, Cleveland)*

The cemetery of **Norton** is situated between the villages of Billingham and Norton-on-Tees approximately ten kilometres inland from the coastline of North Yorkshire and was the most northern British site in the current study (Map 1). Occupying the slope of a low (19 m OD) sand and gravel terrace overlooking the marshy stream valley of the Billingham Beck, the cemetery of Norton was accidentally discovered by children in 1982. Between 1983 and 1985, Teesside Archaeological Unit excavated what is thought to be almost the entire cemetery. A total of 117 inhumation graves and three cremation burials were discovered dating from ca. 520 to 620 AD. Sixty-three (55 percent) of the 117 graves had been disturbed by later features such as gullies or later graves cutting into the original burial. Two graves contained no traces of human bones. Although, until prior to its discovery, the cemetery area was used as a recreation ground, it was ploughed during the 1940s and this accounted for the majority of disturbances. Since the topsoil was very shallow, it was stripped manually revealing that almost half of the burials had been placed just below the topsoil with no discernable grave cuts. Alternatively, the inhumations were located in shallow hollows with the head and feet placed slightly higher and therefore more prone to disturbances. The boundaries of the cemetery were thought to extend to the beck in the east, to a pathway in the north and to a system of prehistoric ditches in the west and south. No signs of settlement remains were detected in the surrounding area. The layout of the cemetery appeared to be in rows with two groups of different alignments – one western group was orientated north-south, while the graves in the east were probably radiating out from a tentative prehistoric feature in the south. However, exceptions to these patterns occurred and some graves seemed to be laid out in plots rather than rows (Sherlock and Welch, 1992).

The human remains were curated at the Archaeology Service for Teesside in Hartlepool (North Yorkshire) during the time of analysis in June-July 2000. A total number of 126 individuals were studied, with many coming from disturbed interments where more than one individual was present. The specialist report by M. Marlow and D. Birkett published in the site report (Marlow and Birkett, 1992) has been the only analysis conducted on the Norton skeletons prior to the present study.

4.1.4 *Neresheim (Ostalbkreis, Baden-Württemberg)*

The modern town of **Neresheim** is situated on the eastern part of a mountainous area known as the *Schwäbische Alb* (the Swabian Mountains), which extends in an easterly direction for several hundred kilometres into the state of Bavaria (Map 1). While Neresheim lies within the shallow basin of the River Egau (504 m OD), a tributary to the Danube, the surrounding hills reach heights of 600 m OD. Repeated finds of skeletal remains and objects dating to the early medieval period have been reported at least since 1900, but archaeological excavations took place only 75 years later when the construction of a housing estate made rescue excavations necessary. Between 1975 and 1976 the *Landesdenkmalamt* Baden-Württemberg, Stuttgart (State Department for the Protection of Prehistoric and Historic Sites) unearthed 151 inhumation graves. The area was formerly used by a garden centre, and the erection of greenhouses probably led to the destruction of further shallow graves, as might be inferred by the open areas within the cemetery layout. Most of the graves were orientated in rows aligned in a west-east direction with a small grave group in the southwest showing a slightly different orientation (Knaut, 1993: Plate 66). The humus, as well as the underlying soil which consisted of loam and eroded chalk, was removed by a mechanical excavator until the grave cuts were visible. Presumably, further excavation took place by hand, although this is not specifically mentioned in the cemetery report. Sixty-five percent of the graves were disturbed with a majority (44 percent, or 66 of 151 graves) of them by deliberate grave robbing, which led to the occasional spread of skeletal elements within and sometimes even between graves. The remaining graves were disturbed by modern intrusions and later grave cuts. The use of the cemetery was dated by grave-goods to between the first half of the fifth century and 700 AD. A contemporary settlement remained undetected, but it may be found underneath the present-day village (Knaut, 1993).

The human remains are curated at the Osteological Collection at the University of Tübingen (OSUT), where 179 individuals were analysed between August and October 2000. The Neresheim skeletons have been studied numerous times before the present analysis took place. The only comprehensive examination of the skeletal sample was carried out by R. Hahn and her findings are published in the site report (Hahn, 1993). Further publications included case studies of individuals with specific pathological lesions (e.g., Hahn and Czarnetzki, 1980; Scholz, 1996), investigations into the congenital absence of teeth (Alt, 1990) and isotope studies for nutritional reconstruction (Schutkowski and Herrmann, 1996; Schutkowski, 2000). A number of dissertation projects involved dental remains from Neresheim (e.g., Born, 2001; Elsäßer, 2002) and samples were taken for DNA analysis of multiple burials (Scholz, 2000). Since the Osteological Collection is a teaching collection, it must be assumed that skeletons from Neresheim, as well as from the other two sites studied here, have been used for student practicals. However, no written record of the nature and intensity of student access to these samples are kept. A more general description of the effects of use of osteological collections was undertaken by Caffell (1999; Caffell *et al.*, 2001), who also collected data on the Osteological Collection in Tübingen, detailing curation methods, accessibility of the collection and student supervision.

4.1.5 *Nusplingen (Zollernalbkreis, Baden-Württemberg)*

Situated on the southwestern fringe of the Swabian Mountains, the village of **Nusplingen** lies in the narrow valley of the River Bära at 700 m OD (Map 1). The surrounding hills rise to approximately 900 m OD and today are still quarried for their deposits of laminated limestone. Until the 1950s, the Bära was unregulated and seasonally flooded the valley leaving marshy areas behind. In 1934 and 1935, rescue excavations took place in the northern parts of the village after several skeletons were discovered while foundations for new houses were dug. The excavations were supervised by the *Landesdenkmalamt*, but the actual work was done by untrained labourers of the *Reichsarbeitsdienst*, a state-organized employment programme that provided previously unemployed men with work on construction sites, such as housing-schemes or the *Reichsautobahn*. Of the 279 reported graves, 126 (46 percent) were disturbed. No further records on details of the excavation were kept but a cemetery plan shows grave alignments as well as types of grave-goods (Eble, 1955: Fig. 1). Information on which graves were disturbed was not available, nor is the type of disturbance specified. Although not all of these graves contained human remains, over 100 more or less complete skeletons were brought to the *Institut für Anthropologie und Rassenkunde* (Institute for Anthropology and Ethnogeny) in Tübingen. Unusually for the time, the postcranial bones, and not only the skull, were curated too. After 1945, the Nusplingen sample became part of the osteological collection at the Department of Anthropology and Human Genetics, where a total of 169 skeletons was still curated at the time of the present study in April 2001. The grave-goods fared less well as most of them were destroyed during a fire in the *Landesmuseum* Stuttgart (State Museum of Baden-Württemberg) in 1944. Nevertheless, some descriptions of them survived in preliminary reports, which allows the cemetery to be dated to the middle of the sixth century, lasting until the late-seventh century AD (Veeck, 1933/35; Schahl, 1938/51). A final publication of the cemetery was never achieved, but the skeletal remains were subject to a dissertation (Eble, 1955), focussing on skeletal measurements for population comparisons. Additionally, the skeletons from Nusplingen were used to train students of physical anthropology, but the intensity of this cannot be assessed in the absence of written records. The Nusplingen remains were also the only skeletal series studied for the current project where each bone was marked with its individual grave number so, even in the case of accidental misplacement of bones, they could be reunited with the original burial.

4.1.6 *Pleidelsheim (Kreis Ludwigsburg, Baden-Württemberg)*

The modern town of **Pleidelsheim** occupies a gentle slope on the right riverbank of the Neckar at 200 m OD (Map 1). The row grave cemetery just north of the town contained probably more than 1,000 individuals, which makes it one of the largest early medieval cemeteries in southwestern Germany. The burial place was thought to have been in continuous use from the middle of the fifth century to the late-seventh century AD. Discovered during construction work in 1951, rescue excavations paralleling the ongoing construction of a housing estate took place in 1960, 1964 and 1969. The stray find of an early medieval pottery fragment was taken as evidence for a nearby settlement west of the cemetery (Koch, 2001). Further excavations became necessary after new areas were earmarked for development in 1989. As before, the *Landesdenkmalamt* conducted this rescue work, which finished in 1990 (Stork, 1990), but the final cemetery report was not published until recently and detailed descriptions of excavation methods are missing (Koch, 2001). The soil underlying the humus topsoil was described as chalky with loess inclusions. More than one-third of all graves (50 of 145 graves) were disturbed to some extent, with 56 percent (28 of 50 graves) of them by grave robbers and the remaining by intercutting graves and modern disturbances. The anthropological study by R. Hahn included data on the age and sex of the skeletons from the 145 graves excavated in 1969; the remaining 120 individuals from the later excavations were analysed by M. Kunter, who planned a more detailed study of pathological changes (Koch, 2001). Therefore, skeletons excavated after 1969 were not available for the present analysis, which took place at the Osteological Collection in Tübingen during the summer of 2001 (August-September) and comprised a total of 147 individual skeletons. Apart from the anthropological assessment described above, dental remains from Pleidelsheim skeletons excavated in 1969 were subject to analysis during a dissertation project on dental disease (Kölbel, 1997).

All skeleton numbers used in this dissertation were adapted from the original grave catalogues or in the case of Nusplingen from the inventory book of the Osteological Collection in Tübingen. An additional prefix denotes the different cemeteries; these are: AP=Apple Down, CS=Castledyke South, NT=Norton, NE=Neresheim, NU=Nusplingen and PL=Pleidelsheim.

4.2 Methods

4.2.1 Recording of skeletons

For several reasons detailed bone and tooth inventories are crucial in osteological analyses. Since skeletal remains in general are far from complete, disease prevalence rates should ideally be expressed as the number of observed skeletal elements with a specific disease divided by the number of skeletal elements available for analysis (Waldron, 1991a; 1994). This made it necessary to develop a recording form with details not only on overall preservation, but also on every individual bone and joint surface. The recording form developed for the present study was based on Buikstra and

Ubelaker's (1994) recommendations, but more emphasis was given to recording the preservation of skeletal elements that potentially may show signs of disease. A recording sheet was created for each skeleton, detailing age-at-death, sex, stature, tooth and bone inventories and a description of pathological lesions. An example of such a recording sheet is presented in Appendix A. All skeletal elements were then coded for their presence and completeness of teeth and bones, and results were entered into databases (Appendix B). Individual databases were designed for disease categories (dental disease, trauma, etc.), listing more detailed information on the observed disorders (Appendix C).

4.2.2 Preservation

To facilitate a better comparability between different samples, each of the six skeletal populations were assessed in a uniform way, using several criteria. These included tooth and bone preservation, overall bone fragmentation, as well as the percentage of each skeleton preserved. Following visual inspection, tooth and bone preservation was scored separately into one of the four categories: (1) **good** – no or only slight enamel/cortical erosion and post-mortem damage, (2) **medium** – some enamel/cortical erosion and/or post-mortem damage, and (3) **poor** – heavily eroded and damaged. An additional fourth category (0) was introduced for tooth/bone **absence**. Fragmentation was scored into one of three categories: (1) **low** fragmentation – with no or only little post-mortem fragmentation, (2) **moderate** fragmentation – with approximately half of the bones fragmented, and (3) **high** – with more than 50 percent of the bones broken. Again, the completeness of each skeleton was scored into one of three stages: (1) **complete** – with more than 75 percent preserved, (2) **partial** – with between 25 percent and 75 percent present and (3) **poor** – with less than 25 percent preserved.

4.2.3 Sex determination

Besides age-at-death determination, the estimation of sex is one of the fundamental requirements for any further analyses of skeletal remains. To determine the sex of adult individuals (here individuals over 16 years of age), morphological changes of the pelvis and skull were examined macroscopically using the criteria summarized by Buikstra and Ubelaker (1994). Compared to pelvic traits the use of features of the skull is less accurate (Ali and MacLaughlin, 1991), as the robusticity of certain landmarks is evaluated and these rather reflect activity patterns than biological differences. Using the more highly dimorphic pelvis with its adaptation to childbearing and birth in females, an accuracy in sex determination as high as 98 percent can be achieved (Krogman and İşcan, 1986). To obtain reliable results, a combination of several features was used to determine sex in the six study samples. Fifteen traits for the pelvis and skull were identified, respectively. For the pubic bone, these comprised the occurrence of the ventral arc, the subpubic concavity and angle, and the ischiopubic ramus bridge (Sutherland and Suchey, 1991). On the ilia, the elevation of the auricular surface, the shape of the greater sciatic notch and the iliac crest, as well as the presence of the preauricular sulcus, were scored. However, recently it was argued that the latter might rather be associated with pelvis shape and size than with sex (Mays and Cox, 2000). Moreover, the preauricular sulcus was described as a non-metric trait (Finnegan, 1978). Additionally, the orientation of the acetabulum, the shape of the obturator foramen and the presence or absence of the *arc composé* were recorded (Sjøvold, 1988). On the sacrum, the size of the sacral alae, the anterior sacral curvature and the sacral auricular surface were observed.

Features of the skull comprised the glabellar profile, supraorbital ridges and the shape of the superior orbital margins (Graw *et al.*, 1999), while on the temporal bone, the suprameatal crest, in addition to the size and orientation of the mastoid processes, were assessed. Further cranial traits include the robusticity of the zygomatic bone and the zygomatic processes. Characteristics of the posterior skull included the appearance of the nuchal area and the external occipital protuberance. On the mandible the projection of the mental eminence, the thickness of the lower mandibular margin and the angulation and shape of the gonion were used (Acsádi and Nemeskéri, 1970). Additionally, a widely unknown method based on the angulation of the internal acoustic meatus was employed. This angle is perpendicular in females, while it is more acutely-angled in males (Wahl, 1982; Ahlbrecht, 1997; Forschner, 2001). This is best measured by inserting a small piece of soft plasticine into the internal acoustic meatus. The advantage of this method lies in the high survival rate of the dense petrous part of the temporal. However, as it was developed on modern forensic cases of known sex the applicability to archaeological remains would have to be proven. Each of the described traits was scored as either female, male, or ambiguous. In the case of discrepancies pelvis and skull, pelvic features were preferred, as these are more consistent with the actual sex of an individual. Especially elderly females tend to display more male traits which may be due to hormonal changes (Ruff, 1981). On the other hand, young males tend to show more female traits (Walker, 1995).

Furthermore, another sexing method using metrical data was applied. These include diameters of the humeral and femoral heads in addition to the radial head diameter, the femoral bicondylar width, the width of the scapular glenoid fossa and the length of the clavicle. All measurements followed the definitions and methods described by Buikstra and Ubelaker (1994) and were made with the same pair of digital sliding callipers (Mitutoyo Absolute Digimatic). Measurements from the left body side were preferred, but were substituted by right side dimensions in cases where the left was not available. Population-specific sectioning points were calculated for both of the sub-samples by adding the means for female and male measurements from individuals with sex attributed using pelvis and cranial features, and then averaging the results. Individuals with measurements greater than the sectioning point were classified as possible male, while those below the sectioning point were assigned as possible females (Tables 3.1 and 3.2).

British samples	N	Mean	Sectioning point	Range	Overlap
Humeral head diameter			42.68		41.4-45.9
Females	52	39.75		36.2-45.9	
Males	31	45.61		41.4-51.3	
Femoral head diameter			45.72		43.1-49.1
Females	85	42.81		36.0.49.1	
Males	58	48.63		43.1-56.3	
Radial head diameter			22.83		20.5-24.6
Females	48	21.22		18.7-24.6	
Males	34	24.44		20.5-29.7	
Femoral width			75.54		74.0-76.9
Females	34	71.1		63.4-76.9	
Males	23	79.97		74.0-93.9	
Scapular width			27.04		25.7-29.1
Females	53	25.17		21.3-29.1	
Males	40	28.91		25.7-32.7	
Clavicular length			145.85		136-155
Females	39	138.31		125-155	
Males	28	153.39		136-175	

Table 3.1 Sectioning points used for metrical sex assessment – British samples (N=number of measurements).

German samples	N	Mean	Sectioning point	Range	Overlap
Humeral head diameter			41.56		36.4-44.1
Females	37	38.58		33.1-44.1	
Males	34	44.54		36.4-52.6	
Femoral head diameter			45.4		41.5-51.4
Females	87	42.49		36.8-51.4	
Males	61	48.3		41.5-55.8	
Radial head diameter			22.51		20.0-24.6
Females	33	21.07		19.0-24.6	
Males	24	23.95		20.0-27.7	
Femoral width			74.15		65.7-74.7
Females	19	69.0		61.5-74.7	
Males	17	79.31		65.7-91.6	
Scapular width			26.74		23.5-28.1
Females	60	24.67		19.8-28.1	
Males	44	28.8		23.5-33.1	
Clavicular length			142.76		132-151
Females	37	138.4		125-151	
Males	33	147.12		132-164	

Table 3.2 Sectioning points used for metrical sex assessment – German samples (N=number of measurements).

A definite sex was only assigned to individuals where more than three features of the pelvis and/or skull were scored unambiguously for the same sex (F=female, M=male); a tentative sex was ascribed to individuals where up to three traits were available for observation. Individuals who could only be sexed by metrical data were placed into a tentative category (?F=possible female, ?M=possible male). Lastly, no sex (N/D=adult of undeterminable sex) was assigned to skeletons with ambiguous traits or where none of the relevant skeletal elements were preserved. It is common practice in palaeodemographic analysis to present data on the number of females and males as pooled results for tentatively and securely identified sexes. However, a dissimilar approach was followed in the current study where all tentatively sexed individuals were treated as adults of undeterminable sex. Although this clearly increased the number of skeletons in this sex category, a different approach would have introduced a high number of unreliably sexed individuals.

In this dissertation, non-adults were not sexed as available macroscopic and metrical methods are felt to be far from reliable, although various methods have been published (e.g., Hunt and Gleiser, 1955; Boucher, 1957; Weaver 1980; Rösing, 1983; Schutkowski, 1986; 1989; 1993; Hunt, 1990; Mittler and Sheridan, 1992; Holcomb and Konigsberg, 1995; Molleson *et al.*, 1998).

4.2.4 Age determination

(i) Adult age

Adult age estimation has often been described as an art and not a science, and it has been widely accepted that the assessment of biological age and its conversion into chronological age comprises numerous pitfalls. This is especially true for elderly individuals, where macroscopic ageing methods consistently fail in accuracy. In the current study, adults were defined as individuals assumed to be older than 16 years. The age of 16 was chosen to obtain ten-year intervals for all adult age categories. The following categories were defined: young adult (16-25 years), young-middle adult (26-35 years), middle adult (36-45 years) and old adult (45+ years). In the case of missing or ambiguous data, the individual was assigned to the 'adult' category.

The methods used in this study were chosen for the following reasons: they had to be non-destructive, ruling out histological and microscopic techniques, they had to be easy to use, because of time restrictions, and they should have been developed on reference samples comparable to the populations analysed in this study. To allow for individual variation in the rate of ageing and the problems in accuracy of individual ageing methods, an approach of using multiple ageing techniques was taken, as advised by Kemkes-Grottenthaler (2002). However, it has to be borne in mind that the sum of even a large number of inaccurate methods will still not produce an exact age estimate. The construction of life tables that tabulate mortality, survivorship and likelihood of dying for individuals by 5-year age bands is customary in bioarchaeology (e.g., Stloukal, 1982; Roth, 1992; Chamberlain, 2000). Due to the likely under-representation of non-adults and problems with accuracy in adult ageing, life tables were not used in the current study. As many methods as possible were applied to each individual skeleton, depending on the state of preservation of the specific anatomical elements. Ageing methods comprised of the techniques listed here; these are followed by a short discussion of their merits and weaknesses:

(a) Dental attrition I (Brothwell, 1981)
(b) Dental attrition II (Miles, 1963)
(c) Ectocranial suture closure (Meindl and Lovejoy, 1985)
(d) Pubic symphysis (Brooks and Suchey, 1990)
(e) Auricular surface (Lovejoy *et al.*, 1985)
(f) Sternal end of ribs (Loth and İşcan, 1989)

With the exception of the pubic symphysis ageing method, none of the other techniques was judged to be precise enough to be used as the sole indicator to determine adult age. For this reason, age was established using at least two independent skeletal indicators. Additionally, young adults (16-25 years) were evaluated using the stage of union of several late-fusing epiphyses and apophyses such as the iliac crest and ischial tuberosity, the vertebral endplates, as well as the medial clavicle and the first two segments of the sacrum. In addition, union of the spheno-occipital synchondrosis on the base of the skull was evaluated. Late-closing epiphyses usually all fuse before 25 years (Molleson, 1986: Table 2). However, some variation may occur, especially for the medial clavicle, where the epiphysis might not close until the age of 30 years (Black and Scheuer, 1996a). Furthermore, the development of the third molar root was assessed using Smith's standards (1991).

(a) Dental attrition

"It is not uncommonly desirable to estimate the age of the subjects from skeletal material; ...it is not uncommon for the bony parts to be so fragmentary that the teeth, which tend to survive much longer than other parts of the skeleton, provide the sole basis for an age estimation" (Miles, 1963: 191). Studying the degree of molar wear is a long-established method of age estimation (Zuhrt, 1955; Rösing and Kvaal, 1998). The first molars show the greatest degree of wear since they erupt approximately six years before the second molars. Standards were developed by Miles (1962; 1963) and Brothwell (1981) both of whom defined a series of age categories based on British samples by analysing the amount of wear of dental enamel. According to Lovejoy (1985), dental attrition remains one of the most dependable methods of age assessment, although certain assumptions have to be made about the regularity of wear occurring on each of the three molars, which may be more pronounced on the first molar owing to mechanical stresses and wear rates not being uniform (Smith, 1984). In addition, there should ideally be a sample of juveniles in the group under study in order to calibrate the rate of wear for the population as suggested by Miles (1963).

Both dental attrition methods were used in this study, because they were found to be most appropriate in terms of population similarities, with both techniques developed on English skeletal remains. Despite these parallels, certain problems arise from the fact that the reference samples were of archaeological origin and, therefore, true age-at-death remains unknown. In addition, no allowance was made for possible differences between the sexes, although Richards and Miller (1991) have demonstrated that no disparities occurred in an Australian aborigines sample of known age and sex, but there are differences in the rate of wear between the first and second molars. On the other hand, Molnar and co-workers (Molnar, 1971, Molnar *et al.*, 1983, McKee and Molnar, 1988) found sex-related differences, with females having significantly more severe wear. Besides this unresolved problem, attrition rates may vary not only due to differences in the consumed diet between different populations but also within human groups caused by differential access to food items. Divergences may occur also because of pathological dental conditions, e.g. ante-mortem tooth loss of one or more molars would invariably increase the stresses put on the remaining teeth.

(b) Cranial suture closure

The bones of the cranium gradually fuse during adulthood, until the sutures become obliterated (Szilvássy, 1988). In many individuals, by the age of 50 or 60 most of their cranial sutures become fused. However, the process by which this occurs is irregular and in some people does not happen at all, and this lack of suture closure is more likely to occur in females than males (Massett, 1989). Cranial suture closure assessment is probably the oldest method to systematically evaluate age-at-death in skeletal human remains and early attempts to correlate advancing suture obliteration with chronological age have been numerous (e.g., Frédéric, 1905; Todd and Lyon, 1924; 1925a; 1925b; 1925c). Despite all these efforts, ageing techniques that involve cranial suture closure have met considerable criticism (Brooks, 1955; Power, 1962). However, Perizonius (1984) reported good results for his method combining endocranial and ectocranial suture closure, which was developed on a late-nineteenth century known-age sample from Amsterdam. Tested on an approximately contemporaneous known-age sample from Christ Church, Spitalfields, London, the reliability of Perizonius' method could not be replicated (Key *et al.*, 1994), and neither was Meindl and Lovejoy's (1985) technique of ectocranial suture assessment particularly reliable when tested on the Spitalfields population. Nevertheless, Meindl and Lovejoy's method was chosen to assess cranial suture closure in the study samples when no other ageing methods were applicable due to lack of preservation of the necessary skeletal element.

(c) Pubic symphysis

One of the most commonly employed methods of age estimation in archaeological (and forensic) cases is based on the evaluation of degenerative changes in the pubic symphysis. The joint that unites the two opposing symphyseal surfaces is classified as fibrocartilaginous (Platzer, 1978). Degenerative changes are therefore less likely to be influenced by weight bearing or activity patterns and might more closely associate with changes brought on by advancing age. The method for assessing these changes was first developed by T.W. Todd (1921a; 1921b), an English anatomist. Gilbert and McKern (1973), Brooks (1955), as well as Brooks and Suchey (1990) developed the method further and plaster casts are used for comparison with archaeological material. The Suchey-Brooks method was considered most appropriate for comparison with the archaeological material analysed in the current study as it was based on a large male sample covering a wide age range, although the female sample was slightly smaller. Brooks and Suchey (1990) state that males are easier to assess than females because their pelves are not affected by childbirth. Greatest accuracy is achieved with this method between the ages of 20 and 40, where the standard deviations are small.

The 'Complex Method' advocated by the Workshop of European Anthropologists (Ferembach *et al.*, 1979; Workshop of European Anthropologists, 1980) and often used in German studies of archaeological human remains, also makes use of changes seen on the pubic symphysis. The technique was developed by Acsádi and Neméskéri (1970) on post-mortem examinations of Hungarian road accident victims. However, their known-age sample consisted of only 105 individuals, 61 males and 44 females, and there were very few young individuals. Furthermore, no sex-specific charts were developed and occupation or dietary status, which might have influenced degenerative changes on the pubic bone, were not taken into account. The shortcomings of the Complex Method have been detailed by Molleson and Cox (1993), who tested this method on the known-age sample of Christ Church, Spitalfields, London. Since it was confirmed that the Complex Method leads to serious deviations from chronological age, it was not used in the current study.

(d) Auricular surface

Age-related changes of the joint surface of the ilium, which forms the articulation with the sacrum, were assessed by Lovejoy and co-workers (1985). This area of the human skeleton is particularly useful, because in the archaeological record it tends to survive better than the pubic symphysis. However, the observed changes can be more difficult to quantify as only photographs of individual stages of auricular surface morphology are available for comparison. Furthermore, in a study of interobserver error of this method applied to a group of soldiers from Snake Hill, Ontario, Canada, Pfeiffer and Williamson (1991) found a considerable difference in results from different observers and age-overestimations occurred in many cases. However, the technique was found to be useful for ageing individuals older than 40 years of age.

(e) Sternal rib ends

This technique, which was developed for forensic purposes in the United States, is relatively easy to use with the help of plaster casts for comparison with the archaeological sample. Kerley (1970) noted a progression in the stages of degeneration at the junction between the rib ends and the cartilage which forms a strong link with the sternum. A system was established by İşcan and co-workers (1984a; 1984b; 1985), which evaluated the shape and depth of the pit formed at the costochondral junction and the increasing irregularity of the pit's wall. Originally designed only for the fourth rib, the third and fifth ribs may also be evaluated. Although a number of studies to help with rib differentiation have been published (Dudar, 1993; Mann, 1993; Hoppa and Saunders, 1998), in fragmented human skeletal remains, the identification of any specific rib, apart from the first and last two pairs, may be difficult.

(ii) Non-adult age

Skeletal remains of human foetuses and children are rarely found in archaeological samples, presumably because of their small size and/or differential burial practice (Scheuer and Black, 2000a). Foetuses were classified as individuals under the age of 40 weeks gestation. The following methods were used to estimate age of prenatal individuals. Standards of age estimation using long bone length were developed by Scheuer and co-workers (1980), using linear regression equations. Measurements were conducted on the left side (when available), using digital sliding callipers. The average of all bone measurements possible in an individual was calculated to receive a final age estimation. In the absence of long bones, measurements of the *pars basilaris* of the occipital bone were used to estimate age. A correlation between size and chronological age was found by Scheuer and MacLaughlin-Black (1994) who developed their method on individuals of known-age from nineteenth-century England. Additionally, an approximate age estimation can be achieved using the development of the tympanic plate of the external acoustic meatus, indicating late foetal or early neonatal individuals (Weaver, 1979; Curran and Weaver, 1982).

The most accurate age estimation of non-adult individuals can be achieved by assessing dental development, as it is thought to be less affected by disease and environmental factors. The standards used in the present study derived from Moorrees and co-workers (1963a; 1963b) for the development and resorption of the deciduous dentition and the development of the permanent dentition. The method benefits from small standard deviations and a large sample size on which the study was based. To account for individuals of unknown sex, the values provided for the permanent mandibular dentition tabulated for girls and boys (Smith, 1991) were averaged to compensate for the fact that non-adults could not be assigned a sex. Results for each individual's assessable teeth were averaged to achieve a final age estimate. However, teeth with complete apexes could not be used, since it is impossible to know how long before death this developmental stage was reached. Due to its great variability, the deciduous canine was not used to estimate non-adult age (Saunders *et al.*, 1993b).

Only when no teeth were present, the rate and extent of epiphyseal union was used to estimate age in non-adults. During the period of growth, the bones extend in length by growth at the metaphysis. This is a cartilaginous growth plate that separates the epiphysis (the secondary growth centres) from the shaft of a long bone (Ortner, 2003). All theses plates finally ossify during adolescence and young adulthood and growth ceases. By then, a total of 450 primary and secondary growth centres have contributed to the formation of 206 bones normally seen in the human skeleton. The age at which this happens varies between the sexes and between people of different ethnic origins. Girls tend to achieve bone maturation approximately two years earlier than boys (Molleson, 1986). A variety of maturation standards based on modern populations are available (for a summary see Scheuer and Black, 2000b). Some standards are based on radiographic examination and they tend to provide higher age estimates. This is due to the fact that although fusion lines may appear to be closed macroscopically, they can still be seen on a radiograph. Fusion was graded macroscopically as 'non-union', 'partial union' and 'complete union' following the definitions described by Buikstra and Ubelaker (1994). Bone maturation age was assessed using information provided by Gray (1998) and Schwartz (1995).

Finally, measurements of all available long bones were carried out with an osteometric board and measurements were recorded to the nearest millimetre. When present, bones from the left side were used. Reconstructed bones were only used in cases where the glued ends met closely. Age estimates deriving from long bone measurements were based on published data collated by Stloukal and Hanáková (1978) and Hoppa (1992). However, it has to be remembered that data on long bone length derived from healthy modern children might not be applicable to individuals from different populations and periods prior to the twentieth century. Furthermore, Stloukal and Hanáková (1978) used dental age standards which were not further defined, although they stated that rather than evaluating tooth eruption, they assessed tooth development. However, their ninth-century AD archaeological non-adult sample was not aged by independent means. Similarly, the German archaeological sample included in Hoppa's research (1992), using original data by Sundick (1978), was aged by tooth developmental standards, using results from Schour and Massler (1941), supplemented by data from Moorrees and co-workers (1963a; 1963b). This might have let to differences in age categories compared to the current study, which were based on Moorrees and colleagues' data alone.

4.2.5 Stature estimation and non-adult growth profiles

(i) Adult stature

Adult stature was calculated by inserting long bone length into regression formulae developed by Trotter and Gleser (1952; 1958; 1977; Trotter, 1970). In the present study, measurements of lower limb bones were preferred, since these are more closely correlated with body height than upper limb length measurements. When present, combined measurements for the femur and tibia were chosen; bones from the left side of the body were selected, but were substituted with measurements from the right side when the left was not preserved (Buikstra and Ubelaker, 1994), and no pathological bones – e.g., bones with healed fractures – were used for calculating stature. Since separate formulae for males and females exist, only adult individuals – i.e., individuals with fused long bone epiphyses – who could be reliably sexed on grounds of their pelvic and cranial features were used. All measurements were taken with an osteometric board and results were presented in centimetres rounded to two decimal points. The age reduction factor for individuals over the age of 30 years, introduced for forensic cases (Trotter, 1970), was ignored as age determination for archaeologically derived adult remains includes a high factor of uncertainty. To assess whether the precision of measurements influenced results, 20 femora from the site of Norton were re-measured. The following equation was used to calculate the technical error of measurement (TEM):

$$TEM = \Sigma D^2/2N$$

where D is the difference between measurements and N is the number of bones measured (Ulijaszek, 1998). The TEM found for 20 measurements of Norton femora was 0.39 cm. It was concluded that the measurement error was low and it might be expected to find similar values for the other five study samples.

(ii) Non-adult growth profiles

To evaluate possible differences in non-adult growth between the study samples mean femur length was plotted against mean dental calcification age. Diaphyseal length of the femur was recorded to the nearest millimetre using an osteometric board. The femur was chosen for two reasons: firstly, lower limb bones, and among them especially the femur, are more sensitive to environmental stress and therefore reflect possible stunting of growth better than any other long bone (Israelsohn, 1960; Eveleth and Tanner, 1990) and, secondly, femoral diaphyseal length was the single-most often possible measurement in non-adult individuals from both study samples. However, the number of measurements within each age class was variable. In cases where no measurements were available, a mean estimate was provided. Because of the low number of individuals within each age class, no statistical tests of significance were conducted to prove whether differences were obtained by change. Furthermore, no comparison of stature between individuals with and without stress indicators such as cribra orbitalia and enamel hypoplasia was performed, since the number of individuals was not high enough to warrant this procedure.

4.2.6 Diagnosis of pathological conditions

(i) Dental disease

Deciduous and permanent teeth were analysed separately and, as maxillary and mandibular teeth and alveolar processes might be affected differentially, upper and lower jaws were also treated separately. However, as there is usually no side prevalence in dental disease, teeth and alveolar sockets from left and right sides were combined to allow for less cumbersome tables (Hillson, 2001). All dental remains were analysed macroscopically under a good light source, using a magnifying glass in doubtful cases.

Dental caries was recorded when a carious cavity was present; enamel discolorations were not regarded as evidence for dental caries as they can be the result of diagenetic factors and other pathological conditions such as fluorosis. All individuals with at least one observable tooth were included and only fully erupted teeth were used in the analysis. A dental probe was not employed as it might lead to the over-diagnosis of dental caries. The location of carious cavities was differentiated into crown and root caries with a further differentiation of crown caries (occlusal, mesial and distal cemento-enamel junction, buccal and lingual smooth crown surface, and gross caries where more than one-half of the crown was destroyed). However, due to time restrictions, no attempt was made to count all observable tooth surfaces as proposed by Hillson (2001); therefore, the true prevalence of caries is likely to be underestimated. Furthermore, caries frequencies are also underestimated because an unknown percentage of tooth loss during life was probably caries induced. However, a caries correction factor was not used, because of problems with this method, which assumes that all or a hypothetical percentage of ante-mortem tooth loss is due to caries. However, teeth might be lost during life for other reasons than dental caries.

Dental calculus deposits were scored for individuals with at least one erupted tooth present. A more detailed analysis by individual teeth and different types of calculus either affecting the tooth crown (supragingival deposits) or the tooth root (subgingival deposits) seemed not to be practical, since many of the teeth from the German samples had clear signs of calculus deposits being lost probably due to post-excavational handling. On the contrary, the dentitions of the British site of Apple Down were left uncleaned by previous researchers, with chalky deposits from the burial environment still attached to the teeth mimicking dental calculus deposits.

Periapical lesions were recorded when a drainage sinus had occurred either on the buccal or lingual aspect of the alveolar bone or within the floor of the maxillary sinus. Sometimes a periapical lesion was visible due to post-mortem damage to the alveolar bone. As not all periapical lesions develop a sinus, their prevalence in skeletal human remains is underestimated in the absence of radiographs of all alveolar elements. The lack of radiographs also prevented a more detailed differentiation of periapical lesions into abscesses, granulomas and cysts. However, as the presence of a fistula most likely indicates a pus-forming process, a tentative diagnosis of periapical abscess was made. Since periapical lesions are the most common sequels of pulp exposure, this condition was also recorded.

Ante-mortem tooth loss was scored when a remodelled alveolar socket was observed. On an individual basis, all individuals with at least one alveolar socket present were included in the analysis. Likewise affecting the alveolar process, **periodontal disease** was scored to be present when a certain proportion of a tooth's root was exposed. As continuous eruption of teeth can mimic this pathological process, additional pitting and irregularities of the alveolar margin, indicative of an inflammatory process had to be present. Severity was scored in three stages – slight, medium and severe – according to the criteria outlined by Brothwell (1981). Nevertheless, due to time restrictions, this data was not incorporated in the analysis.

Enamel hypoplasia can be manifest as horizontal lines, grooves or pitting. Hypoplastic defects were recorded as present when it was possible to feel a defect by running a fingernail over the tooth's labial surface. Since hypoplastic lines can form as a response to traumatic insults usually seen on isolated teeth, only defects occurring on more than one tooth were counted. The prevalence of enamel hypoplasia was analysed for individuals with at least two teeth observable, either erupted or unerupted, as well as for all teeth with defects in relation to the overall number of teeth observable. To determine at which point during a person's life enamel matrix disruption had occurred, measurements were taken from the hypoplastic defect to the cemento-enamel junction (CEJ) of the mandibular canines; this is the tooth most often affected apart from the maxillary incisors (Goodman and Armelagos, 1985). Measurements were conducted with the same pair of digital callipers (Mitutoyo Absolute Digimatic), with measurements recorded to the nearest tenth of a millimetre. To allow for population specific tooth crown height, measurements were taken for mandibular canine crowns with no sign of attrition and the results were pooled for the British and German samples. These measurements were then inserted into the formula discussed by Hodges and Wilkinson (1990: 555) together with the measurements taken for the distance of linear hypoplastic defects from the CEJ to calculate the age-at-stress occurrence. However, there may be severe methodological problems applying dental growth rates from modern healthy children to non-adults from past populations, who might have had different rates of enamel development due to them being less healthy.

(ii) Joint disease (arthropathies)

Only adult individuals in the study samples were found to have experienced joint disease and therefore only adult joint articulations were included in the analysis. Since it has not been proven that severity of observed bone changes correlates with severity of the disease itself, bony changes were not ranked on a scale of severity. **Osteoarthritis** was diagnosed on synovial joints according to the criteria outlined by Rogers and Waldron (1995: 44-45):

> "... foremost on demonstrating the presence of eburnation. Where eburnation is absent, then we suggest that it should be diagnosed only when at least *two* of the following are present: marginal osteophyte and/or new bone on the joint surface; pitting on the joint surface; or alteration in the bony contour of the joint."

Results were presented by individuals affected for specific joint complexes and all skeletons with at least one joint component present were included. In the case of symmetric joints, at least one component from both body sites had to be present. Additionally, prevalence for the number of joints affected, separated by left and right body site, was conducted. Joint complexes were defined as the following:

- temporo-mandibular joint (mandibular fossa, mandibular condyle),
- sterno-clavicular joint (sternal end of clavicle, clavicular articulation of manubrium),
- acromio-clavicular joint (acromial end of clavicle, clavicular articulation of acromion),
- gleno-humeral or shoulder joint (glenoid fossa, head of humerus),
- elbow joint (capitulum and trochlea of distal humerus, radial head, ulnar trochlea, radial notch of ulna),
- wrist joint (scaphoid and lunate articulation of distal radius, distal ulna, scaphoid, lunate and triquetrum)
- hands (articulations of carpals, metacarpals, hand phalanges),
- hip joint (acetabulum, head of femur),
- knee joint (medial and lateral femoral condyles, medial and lateral tibial condyles, patellar surface of femur, medial and lateral articular facets of patella)
- ankle joint (distal tibia, trochlea of talus, lateral malleous of fibula, fibula articulation of talus)
- foot (tarsals, metatarsals, foot phalanges),
- costo-vertebral joints (head and tubercles of ribs),
- vertebral facets joints (superior and inferior apophyseal joints, articulation of *dens axis* on atlas, atlas articulation of axis).

Specific problems were encountered when quantifying hand and foot joints as they consist of a variety of synovial and cartilaginous joints. Since it was not attempted to investigate the distribution of degenerative changes within the hands and feet, all synovial articulations were pooled for hand and foot into joint complexes. Hand and foot joints were deemed present when one or more articular facets were preserved. This method will of course lead to an underestimation of the actual prevalence, since joints that were not present might have been affected by osteoarthritis.

Furthermore, costo-vertebral articulations were only scored for heads and tubercles of the ribs, because in fragmented skeletal human remains it is often not possible to identify the corresponding articulation on the vertebral body and transverse spinal processes. Since rib preservation varied considerably even within samples, only individuals with more than half of their ribs present, six from each side, were considered.

Degenerative disk disease was identified as a combination of vertebral endplate pitting or irregularities due to new bone formation, in addition to osteophyte formation at the margins of vertebral bodies; marginal osteophytes alone were not considered as diagnostic of degenerative disk disease as, on their own, they can be part of a variety of conditions, such as ankylosing spondylitis, fluorosis and trauma or they may be age-related (Rogers and Waldron, 1995: Table 3.2). Additionally, small areas of sclerotic bone or eburnation were considered to represent this condition. Results were given by individuals affected at each site, including all skeletons with at least one observable vertebral body surface. Additionally, the number of affected vertebrae, or rather individual superior and inferior endplates were analysed, although results were ultimately pooled to allow for less cumbersome tables of data.

Schmorl's nodes were diagnosed on vertebral endplates when shallow depressions with remodelled edges were noticed. Recording was undertaken separately for superior and inferior endplates for all individuals with at least one vertebral surface preserved and results were presented for individuals affected, as well as for the number of vertebral body surfaces affected. Again, results for vertebral endplates were combined for reasons of brevity. The number of observable endplates on which calculations were based differed slightly for degenerative disk disease and Schmorl's nodes, because a number of very fragmentary vertebral surfaces displayed Schmorl's nodes and these had to be included in the number of observable endplates.

(iii) Trauma

Only adults were included in the study of **fractures**. For two reasons subadults were not considered: firstly, they were clearly under-represented in the skeletal record, and secondly, non-adult bones are more flexible than adult bone tissue and therefore more likely to display greenstick or incomplete fractures, which tend to become well remodelled with advancing age and are more likely to be missed, during both macroscopic and radiographic examination.

Fractures were identified macroscopically when callus formation and/or angulation was present. Selected doubtful cases were radiographed, although no systematic survey of all fractures by radiography was possible. The completeness of each long bone was assessed by giving a score of completeness for each of the three thirds of the diaphysis. A long bone was deemed complete when at least 75 percent or more of each third of the diaphysis was preserved. Similarly, completeness was assessed for all other bones that were not classified as long bones. Furthermore, incomplete bones displaying fractures were included in the bone count. Additionally, fracture prevalence was calculated by individuals affected, in the case of paired bones, including all individuals with both sides preserved. Trauma analysis was subdivided into different skeletal elements: long bones (including the clavicle), non-long bones (including the mandible) and cranial bones.

The exact position of each fracture, the side affected and, when possible, the type of fracture was also recorded. In the case of well-healed fractures, this had to remain tentative in the absence of radiographic confirmation. However, fractures may heal so successfully that even internal evidence becomes remodelled, thus not showing up on a radiographic film. When present, the non-fractured ipsilateral bone was measured and compared to the affected side, to allow the assessment of presence of overlap following healing. In the absence of the opposite bone, overlap was evaluated by direct measurement of the fractured bone. A noticeable amount of overlap leads to the shortening the fractured element and consequently to problems in neighbouring joints due to changes in the joint morphology. This can ultimately lead to secondary osteoarthritis. Rarely the opposite effect, lengthening of a healed bone, may lead to similar complications. Fracture healing was also assessed by estimating the amount of apposition, or percentage of reunited surface area between two fractured fragments. The angle in which bone fragments had healed was measured with regard to the position of the distal fragment and its alignment to the proximal fragment. In addition to osteoarthritis, other indicators of complications during fracture healing were noted; these comprise of non-union (pseudoarthrosis), infection (periostitis and osteomyelitis), ossification of soft tissue due to trauma, and disuse atrophy.

The same methodology described for long bone fractures was employed to diagnose fractures of other skeletal elements: callus formation and/or angulation. Since most fractures of bones such as the mandible, scapula, hand and foot bones were rare, prevalence was only given for the skeletal population affected as well as for pooled samples. However, rib and metacarpal fractures were more abundant and tables providing detailed information were constructed. Prevalence rates by individuals were calculated including all individuals who, in the case of paired bones, had both sides preserved. In the case of metacarpals, metatarsals and phalanges all individuals with at least one bone present from each side were included. In addition, prevalence by number of bones affected was calculated.

Several forms of **cranial injuries** were found in the study samples. Injuries made by blunt force were identified when depressed areas were found on the skull, indicating healed blunt trauma. Radiating fractures and concentric layers of fracture lines around the point of impact were diagnostic of unhealed blunt trauma. Unhealed injuries caused by bladed weapons were diagnosed following the criteria outlined by Wenham (1989): linearity of the lesion, well defined edges, as well as smooth and polished margins. The presence or absence of parallel scratch marks on unhealed cuts were analysed using a magnifying glass. Additionally, the colour of the cut was evaluated to allow for differentiation of perimortem and post-mortem lesions. A lighter colour than the surrounding bone should indicate post-mortem fracture, whereas identical colour of bone and lesion indicates a perimortem origin (Wakely, 1997). Lastly, healed sharp force injuries were identified in linear lesions where remodelling of the margins had taken place.

In the six study samples, **spondylolysis** was diagnosed when a separation of a vertebral neural arch was detected. Comments on unilateral or bilateral occurrence of spondylolysis were made, and **spondylolisthesis** was diagnosed when a vertebra with spondylolysis had slipped forward on its caudal neighbour and horizontal new bone formation on the anterior margin of the affected and/or neighbouring vertebra was observed. Results are given with regard to the number of individuals affected, as well as for the number of elements affected. Since preservation varies among and between the samples, spondylolysis frequencies were calculated only for individuals with their lumbar spines completely preserved, and not for the entire vertebral column. Furthermore, all individuals with fragmentary spines showing spondylolysis were included. To investigate a possible relationship with other congenital anomalies of the axial skeleton, the occurrence of spondylolysis together with lumbo-sacral transitional vertebrae or spina bifida occulta was analysed.

(iv) Non-specific infections (NSI)

Skeletal evidence for **non-specific infections** was determined by the presence of new bone formation on any bone. There are problems with differentiating periostitis, osteomyelitis and osteitis, especially in the absence of radiographs. Equally, early stages of osteomyelitis may be overlooked due to lack of involucrum and/or cloaca formation. Therefore, periostitis, osteomyelitis and osteitis have been combined under the heading of new bone formation. This newly formed bone can be disorganised and porous (woven) indicating active inflammatory processes or lamellar (remodelled) representing the healed chronic stage. Mixed, woven and lamellar lesions are indicative of recurrent infection or they may indicate that some parts of the lesion healed, while others did not. Results are presented for individual bones (bone count) and individual skeletons (individual count). For the bone count, only completely preserved bones were considered (preservation score 'one'; for a description of preservational stages, see 4.2.2). An exception to this approach were the fragile bones forming the maxillary sinus, where a preservation score of 'two' was additionally accepted. On an individual level, all individuals with both paired bones present plus the number of individuals with single bones showing evidence of non-specific infection were included.

Maxillary sinus analysis was conducted macroscopically and, since in most skeletons some post-mortem damage had occurred, an endoscope was not used. However, the aid of a small torchlight made lesions easier to observe. **Chronic maxillary sinusitis** was diagnosed based on new bone formation in the form of fine spicules anywhere on the maxillary sinus and/or inflammatory fine pitting. Notes were taken on whether spicules were remodelled or not, the latter indicating an active lesion at the time of death. A diagnosis of dentally induced maxillary sinusitis was accepted when oro-antral fistulae, periapical lesions or carious cavities leading to extensive destruction of the tooth's crown and/or ante-mortem tooth loss were seen in individuals with inflammation of the corresponding sinus. Although it has been recognized that subadult sinus development may hinder analysis before the age of six years (Lewis, 2002), in this study non-adults aged two years or older were included, since one individual in the 2-4 years age band displayed new bone formation of the maxillary sinuses. Care was taken not to score developmental pitting as a sign of chronic maxillary sinusitis, and non-pathological tooth root penetration of the sinus floor was differentiated from oro-antral fistulae.

The quantification of **rib periostitis** is also problematic, since ribs are frequently fragmented and incomplete. Only individuals with a minimum of twelve ribs present, regardless of side, were included in the analysis. As there is also a problem with differentiating between growth-related new bone formation and pathological new bone formation in very young children, individuals below two years of age were omitted (Lewis, 2002).

Endocranial lesions were only recorded for individuals with preserved skulls older than 6 months, because of problems with differentiating between normal growth-related and pathological new bone formation. New bone formation was scored either as woven, remodelled or as a mixture of both. In addition, vascular impressions seen on the internal skull were scored. However, it is not yet known whether these different expressions are part of the same pathological process or represent different aetiologies. For this reason, no definite diagnosis of endocranial lesions was attempted.

(v) Congenital and developmental anomalies

Diagnosis of congenital anomalies of the axial skeleton followed the recommendations outlined by Barnes (1994). **Axial congenital anomalies** were studied for all adults with the appropriate vertebrae and sacral base present. **Spina bifida occulta** (SBO) was diagnosed when one or more neural arches had failed to fuse in the adult skeleton. SBO was only diagnosed when it occurred above the level of the fourth sacral element (Buikstra and Ubelaker, 1994) and it was not diagnosed in subadults, since sacral element fusion spans from age 7-15 years. As the time of onset lies in childhood, no attempt was made to calculate frequencies for different adult age categories. Prevalence rates were calculated separately for SBO occurring on sacral and non-sacral elements.

(vi) Metabolic disorders

Cribra orbitalia was diagnosed when some form of pitting on the orbital roof was present. Care was taken not to confuse new bone formation on the outer table of the cranial bones with this condition, as it is associated with other diseases such as scurvy and infection (Ortner and Ericksen, 1997). However, microscopic analysis would be necessary to ascertain whether expansion of the diploë led to the porosity. As no porotic lesions of the cranial vault were encountered in the study samples, only changes consistent with cribra orbitalia were scored. However, a large number of skulls, especially from the German sample of Nusplingen, showed remodelled pitting on the cranial vault, but in the absence of expansion of the diploë, this was not diagnosed as porotic hyperostosis. Similar observations were made by Mann and Murphy (1990) who described an 'orange-skin'-like appearance of unknown aetiology. Likewise, the summary of a conference audience discussion agreed that over-diagnosis of porotic hyperostosis could occur because lesions described as 'minor osteoporotic pitting' were probably due to non-pathological changes of the cranial vault (Stuart-Macadam, 1991a).

Cribra orbitalia was scored on the basis of Stuart-Macadam's system (1991b: 109) with one alteration – her stage I 'capillary-like impressions' was not recognized as indicative of cribra orbitalia. Hence, the following grading was developed:

Stage 0	no pitting
Stage I	scattered fine pitting (<1 mm)
Stage II	large and small isolated foramina (>1<2 mm)
Stage III	larger pits with some coalescence
Stage IV	coalescent pitting
Stage V	trabecular outgrowth from the outer table

To differentiate between active and healed lesions, criteria outlined by Mensforth and co-workers (1978) were used. Active lesions consist of foramina with sharp margins, while healed lesions occurred in the form of rounded margins and 'filled in' pitting. To account for the fragile horizontal plate of the frontal bone which forms the orbital roof, all orbits with a preservational score of 'one' and 'two' were included in the analysis. On an individual basis, skeletons with both their orbits preserved were analysed; additionally, all individuals with less well preserved orbits but signs of cribra orbitalia were included.

Trying to assess whether non-adults with cribra orbitalia were more stunted in their growth compared to their contemporary peers without any evidence of anaemic changes proved to be impossible as the number of individuals within each two-year age category was too small. Even after pooling data within each country, insufficient individuals had all three necessary parameters present (dental calcification age, femoral length, preserved orbital roofs).

In the absence of systematic radiographic analysis in the study samples, **osteoporosis** has been tentatively diagnosed by the presence of specific bone fractures. These comprise of fractures of the femoral neck, the distal radius (Colles' fracture) and vertebral body. Vertebral body fractures include crush fractures and anterior wedge fractures. However, it has to be remembered that all these fracture types can also occur in the absence of osteoporosis. One vertebral body fracture is typical of osteoporosis –

so-called 'codfish vertebrae' – a biconcave deformity found on lumbar bodies (Pschyrembel, 1982). As the number of individuals with proximal femur or distal radius fractures was low, frequencies were calculated for the combined German samples only. For the same reason, no age-specific prevalence rates were calculated. Vertebral body fractures were more common, and frequencies were presented for younger adults and older adults. Younger adults were defined by combining the two younger adult age categories (16-25 years and 26-35 years), while older adults comprised the two older age classes (36-45 years and 45+ years). For the individual count, only skeletons with at least five of their lower seven vertebrae (T11-L5) present were included. These seven vertebrae were selected because they were the most often involved in vertebral body fractures. Additionally, other vertebrae displaying fractures were included when appropriate, but any individual to whom no specific age could be assigned was excluded. However, the number of individuals with vertebral fractures placed in the 'adult' age category was very low; in fact, only three individuals could not be included because of missing age estimates.

4.2.7 Statistical testing

Statistical testing is necessary in order to assess the validity of observed patterns in the collected data (Robb, 2000). The choice of the appropriate statistical test depends on the level of measurement and the organization of the data. Levels of measurements can be nominal, ordinal or continuous. While nominal data represents two different categories such as 'male and female', 'presence or absence', ordinal data can be ranked according to certain criteria such as 'good, medium or poor preservation'. Continuous data includes all measurements such as long bone length.

Types of data organization refer to the number of samples or sub-samples used in the analysis; this can be one sample, two samples or more than two samples. In this study, the choice of statistical test was based on the *Centre for Archaeology Guidelines* (2002) recommendations. As analysed data was found to be on a nominal level, comparing disease prevalence within and between samples and sub-samples, chi-squared tests were employed. In cases where sample size are small (less than five), a correction factor, known as Yates' correction factor, is usually applied (Madrigal, 1995). However, even a correction factor does not increase the accuracy of results and, consequently, no chi-squared tests were performed for expected value sizes below five (Fletcher and Lock, 1994). All calculations were carried out on an Excel98 spreadsheet and results were accepted to be statistically significant at the 5 percent level. This indicates that the value derived from the calculation (p) equals or is smaller than 0.05, leaving a less than 5 in 100 chance that the pattern was generated by chance.

While statistical tests are ordered according to their measurement levels and types of data, osteological data can also be ranked at several different levels. The prevalence of a disease can be studied in an area consisting of several bones (e.g., the elbow), an individual bone (e.g., the radius) or an anatomical unit (e.g., the distal radius). Furthermore, prevalence can be studied separately by sex group and age category or in an entire skeletal sample or in pooled samples. These analytical units might not resemble biological units. For example, the total number of teeth studied for the prevalence of caries might be 320. This could indicate that ten individuals had all of their 32 teeth present; it could equally mean that 320 individuals each had one tooth present. It is therefore important to give information on two levels; by the number of individuals, as well as the number of bones or bone elements used for frequency calculation. Additionally, some observations are not independent from each other. Caries lesions are highly correlated with other dental disease such as abscesses and ante-mortem tooth loss. The application of a chi-squared test to determine whether the prevalence of caries, for example in two subgroups such as males and females, is statistically significant by using the total number of observed teeth in relation to the number of teeth with the disease would be incorrect. Only the number of individuals displaying the observed pathological condition in relation to all individuals with teeth observable should be used. In this case, one has to deal with the problem of missing data, since not all skeletons will have all their teeth preserved. The same applies for all skeletal elements. To accommodate for this shortcoming, each result section will detail the number of individuals used for the specific analysis, as well as the number of bones/teeth.

After having introduced the material and methods used in the study, Chapter Five will detail results for each of the described health and disease indicators.

CHAPTER FIVE

RESULTS

The following chapter presents the results of the current study. Only in Chapter Six will these results be integrated into a discussion of their implications of health and disease patterns in the study populations.

5.1 DEMOGRAPHY

Appendix C1, 'Demographic Structure' provides a summary of demographic data for all individuals of the study samples by site, including sex, age, tooth and bone preservation, bone fragmentation and percentage of each skeleton recovered. Due to the amount of data collated, this information can be found on CD-ROM.

Age ranges were tabulated separately by sex for all adult skeletons; in all tables detailing demographic data, the first percentage (%) refers to the individual sex category, while the second percentage (%*) denotes the value within each age class.

	<16	16-25	26-35	36-45	45+	Adult	Total
Subadults	**29**	0	0	0	0	0	**29** 26.85
Females % %*	0	**3** 6.52 30.0	**20** 43.48 64.52	**16** 34.78 69.57	**5** 10.87 45.45	**2** 4.35 50.0	**46** 58.23
Males % %*	0	**6** 19.35 60.0	**11** 35.48 35.48	**7** 22.58 30.43	**6** 19.35 54.55	**1** 3.23 25.0	**31** 39.24
N/D % %*	0	**1** 50.0 10.0	0	0	0	**1** 50.0 25.0	**2** 2.53
Total %**	**29**	**10** 9.25	**31** 28.7	**23** 20.37	**11** 10.19	**4** 3.7	**108** **(79)**

Table 5.1.1 Demographic profile of Apple Down (%=percentage within row, %*=percentage within column, %**=percentage within age class in relation to all adults, N/D=adults of undetermined sex, ()=number of adult individuals).

The demographic structure of the Apple Down sample is shown in Table 5.1.1. A total of 108 individuals was present for analysis, of whom 29 (26.85 percent) were non-adults (aged below 16 years). Of the 79 adults, 46 (58.23 percent) were judged to be female, 31 were male (39.24 percent) and two were of undetermined sex (2.53 percent).

To test for a balanced distribution between the two sexes, as well as between adults and non-adults, chi-squared tests were conducted. Although female individuals outnumbered males, the difference was not statistically significant (χ^2=2.9221, p=0.0874, d.f.=1). The male to female ratio at Apple Down was 1:1.48. Based on a hypothetical non-adult to adult ratio of 1:2, there was no statistically significant under-representation of subadults in this sample (χ^2=2.0417, p=0.1530, d.f.=1).

	<16	16-25	26-35	36-45	45+	Adult	Total
Subadults	**46**	0	0	0	0	0	**46** 23.12
Females % %*	0	**13** 19.7 54.17	**17** 25.76 48.57	**19** 28.79 50.0	**10** 15.15 66.67	**7** 10.61 17.03	**66** 43.14
Males % %*	0	**8** 15.69 33.33	**17** 33.33 48.57	**18** 35.29 47.37	**5** 9.8 33.33	**3** 5.88 7.32	**51** 33.33
N/D % %*	0	**3** 8.33 12.5	**1** 2.78 2.86	**1** 2.78 2.63	0	**31** 86.11 75.61	**36** 23.53
Total %*	**46**	**24** 15.69	**35** 22.88	**38** 24.84	**15** 9.8	**41** 26.8	**199** **(153)**

Table 5.1.2 Demographic profile of Castledyke South (%=percentage within row, %*=percentage within column, %**=percentage within age class in relation to all adults, N/D=adults of undetermined sex, ()=number of adult individuals).

Table 5.1.2 details the age and sex structure at Castledyke South. Of 199 skeletons, 46 (23.12 percent) were identified as non-adults, while 153 individuals were over the age of 16 years. Of these, 66 were female (43.14 percent) and 51 were male (33.33 percent). A large number of adult individuals (23.53 percent) could not be assigned to either sex. The male to female ratio was 1:1.29. The difference between female and male individuals at Castledyke South was not statistically significant (χ^2=1.9231, p=0.1655, d.f.=1). However, individuals under the age of 16 years were significantly under-represented, as a chi-squared test confirmed (χ^2=9.3513, p=0.0022, d.f.=1).

The demographic structure at Norton can be seen in Table 5.1.3. One hundred and twenty-six individuals were preserved, of which more than one-third were non-adults (34.13 percent), therefore falling within the assumed proportion of non-adults to adults of one-third to two-thirds. Of 83 adults, 35 were female (42.17 percent), 20 were male (24.1 percent), but one-third could not be assigned to either sex (33.7 percent). The male to female ratio at Norton was 1:1.75 and males were statistically under-represented (χ^2=4.0909, p=0.0431, d.f.=1). However, non-adults were not significantly under-represented (χ^2=0.0357, p=0.8541, d.f.=1).

	<16	16-25	26-35	36-45	45+	Adult	Total
Subadults	**43**	0	0	0	0	0	**43** 34.13
Females % %*	0	**5** 14.29 38.46	**10** 28.57 62.5	**10** 28.57 58.82	**4** 11.43 66.67	**6** 17.14 19.36	**35** 42.17
Males % %*	0	**4** 20.0 30.77	**5** 25.0 31.25	**6** 30.0 35.29	**2** 10.0 33.33	**3** 15.0 9.68	**20** 24.1
N/D % %*	0	**4** 14.29 30.77	**1** 3.57 6.25	**1** 3.57 5.88	0	**22** 78.57 77.97	**28** 33.74
Total %*	**43**	**13** 15.66	**16** 19.28	**17** 20.48	**6** 7.23	**31** 37.45	**126** **(83)**

Table 5.1.3 Demographic profile of Norton (%=percentage within row, %*=percentage within column, %**=percentage within age class in relation to all adults, N/D=adults of undetermined sex, ()=number of adult individuals).

The demographic profile of the Neresheim sample can be seen in Table 5.1.4. Of 179 individuals, 34 were under the age of 16 years (18.99 percent). Slightly more than half of all of the 145 adults were female (52.41 percent), 35.17 percent were male and 12.41 percent could not be assigned a sex. The male to female ratio was 1:1.49 and the difference between the number of females and males was statistically significant (χ^2=4.9213, p=0.0265, d.f.=1). Non-adults were significantly under-represented (χ^2=16.5494, p=0.0000, d.f.=1).

	<16	16-25	26-35	36-45	45+	Adult	Total
Subadults	**34**	0	0	0	0	0	**34** 18.99
Females % %*	0	**4** 5.26 40.0	**40** 52.63 75.47	**17** 22.37 56.67	**9** 11.84 36.0	**6** 7.9 22.22	**76** 52.41
Males % %*	0	**5** 9.8 50.0	**13** 25.49 24.23	**13** 25.49 43.33	**16** 31.37 64.0	**4** 7.84 14.82	**51** 35.17
N/D % %*	0	**1** 5.56 10.0	0	0	0	**17** 94.44 62.96	**18** 12.41
Total %*	34 18.99	**10** 6.9	**53** 36.55	**30** 20.69	**25** 17.24	**27** 18.62	**179** **(145)**

Table 5.1.4 Demographic profile of Neresheim (%=percentage within row, %*=percentage within column, %**=percentage within age class in relation to all adults, N/D=adults of undetermined sex, ()=number of adult individuals).

Table 5.1.5 details the sex and age distribution of the Nusplingen sample. A low proportion of non-adult individuals was present at Nusplingen, where only 11.83 percent of all skeletons were under the age of 16. Of 149 adults, 56 were female (37.58 percent), 64 were male (42.95 percent) and 29 could not be assigned to any sex (19.46 percent). The male to female ratio was 1.14:1 and no statistically significant difference existed in the number of women and men (χ^2=0.5333, p=0.4652, d.f.=1). However, non-adults were significantly under-represented (χ^2=35.1455, p=3.0551, d.f.=1).

	<16	16-25	26-35	36-45	45+	Adult	Total
Subadults	**20**	0	0	0	0	0	**20** 11.83
Females % %*	0	**7** 12.5 41.18	**26** 46.43 53.06	**17** 30.36 40.48	**3** 5.36 30.0	**3** 5.36 9.68	**56** 37.58
Males % %*	0	**6** 9.38 35.29	**21** 32.81 42.86	**24** 37.5 57.14	**7** 10.94 70.0	**6** 9.38 19.36	**64** 42.95
N/D % %*	0	**4** 13.79 23.53	**2** 6.9 4.08	**1** 3.45 2.38	0	**22** 75.86 70.97	**29** 19.46
Total %*	**20**	**17** 11.41	**49** 32.89	**42** 28.19	**10** 6.71	**31** 20.81	**169** **(149)**

Table 5.1.5 Demographic profile of Nusplingen (%=percentage within row, %*=percentage within column, %**=percentage within age class in relation to all adults, N/D=adults of undetermined sex, ()=number of adult individuals).

The demographic data for the third German site – Pleidelsheim – can be found in Table 5.1.6. Approximately one-fifth of the 147 individuals were non-adults (20.41 percent). Of 117 adults, slightly more females than males were present (48.72 percent and 41.03 percent). It was not possible to sex twelve adults (10.26 percent). The male to female ratio was 1:1.19, and despite the higher number of females, this difference was statistically insignificant (χ^2=0.7714, p=0.3798, d.f.=1). However, once again, non-adults were under-represented (χ^2=11.0511, p=0.0009, d.f.=1).

	<16	16-25	26-35	36-45	45+	Adult	Total
Subadults	**30**	0	0	0	0	0	**30** 20.41
Females % %*	0	**10** 17.54 55.56	**21** 36.84 61.77	**13** 22.81 40.63	**3** 5.26 37.5	**10** 17.54 40.0	**57** 48.72
Males % %*	0	**7** 14.58 38.89	**13** 27.08 38.23	**18** 37.5 56.25	**5** 10.42 62.5	**5** 10.42 20.0	**48** 41.03
N/D % %*	0	**1** 8.33 5.56	0	**1** 8.33 3.13	0	**10** 83.33 40.0	**12** 10.26
Total %*	30 20.41	**18** 15.39	**34** 29.06	**32** 27.35	**8** 6.84	**25** 21.37	**147** **(117)**

Table 5.1.6 Demographic profile of Pleidelsheim (%=percentage within row, %*=percentage within column, %**=percentage within age class in relation to all adults, N/D=adults of undetermined sex, ()=number of adult individuals).

Table 5.1.7 summarizes the demographic data for pooled British samples and in Fig. 5.1.1 results are detailed for British adult individuals. Of the 433 British individuals, 118 were classified as non-adults (27.25 percent). Assuming that one-third of all individuals who died within a population would be non-adults, there was a statistically significant under-representation of individuals aged under 16 years (χ^2=7.2061, p=0.0073, d.f.=1). Almost half of the 315 adults were females (46.67 percent), while only 102 males were present (32.38 percent). Females were significantly over-represented compared to males (χ^2=8.1325, p=0.0043, d.f.=1). However, 66 adults could not be assigned to either sex (20.95 percent). British females and males had similar mortality profiles within the individual age classes. Most people died as young-middle adults (females: 31.97 percent, males: 32.35 percent), although almost as many individuals were found in the next oldest age class (female: 30.61 percent, males: 30.39 percent). Young adults showed a slightly higher risk of dying compared to old adults. A higher proportion of males died in the young adult age class (females: 14.29 percent, males: 17.65 percent). Among old adults, females and males were more evenly distributed (females: 12.93 percent, males: 12.75 percent). However, a high number of adult individuals were classified as unsexed adults (81.81 percent). In addition, the proportion of females and males to whom no specific age could be assigned (females: 10.2 percent, males: 6.86 percent) have to be considered when demographic profiles of skeletal populations are evaluated.

	<16	16-25	26-35	36-45	45+	Adult	Total
Subadults	**118**	0	0	0	0	0	**118** 27.25
Females % %*	0	**21** 14.29 44.68	**47** 31.97 57.32	**45** 30.61 57.69	**19** 12.93 59.38	**15** 10.2 19.74	**147** 46.67
Males % %*	0	**18** 17.65 38.3	**33** 32.35 40.24	**31** 30.39 39.74	**13** 12.75 40.63	**7** 6.86 9.21	**102** 32.38
N/D % %*	0	**8** 12.12 17.02	**2** 3.03 2.44	**2** 3.03 2.56	0	**54** 81.81 71.05	**66** 20.95
Total %*	**118** 27.25	**47** 14.92	**82** 26.03	**78** 24.71	**32** 10.16	**76** 24.13	**433** **(315)**

Table 5.1.7 Demographic profile of pooled British samples (%=percentage within row, %*=percentage within column, %**=percentage within age class in relation to all adults, N/D=adults of undetermined sex, ()=number of adult individuals).

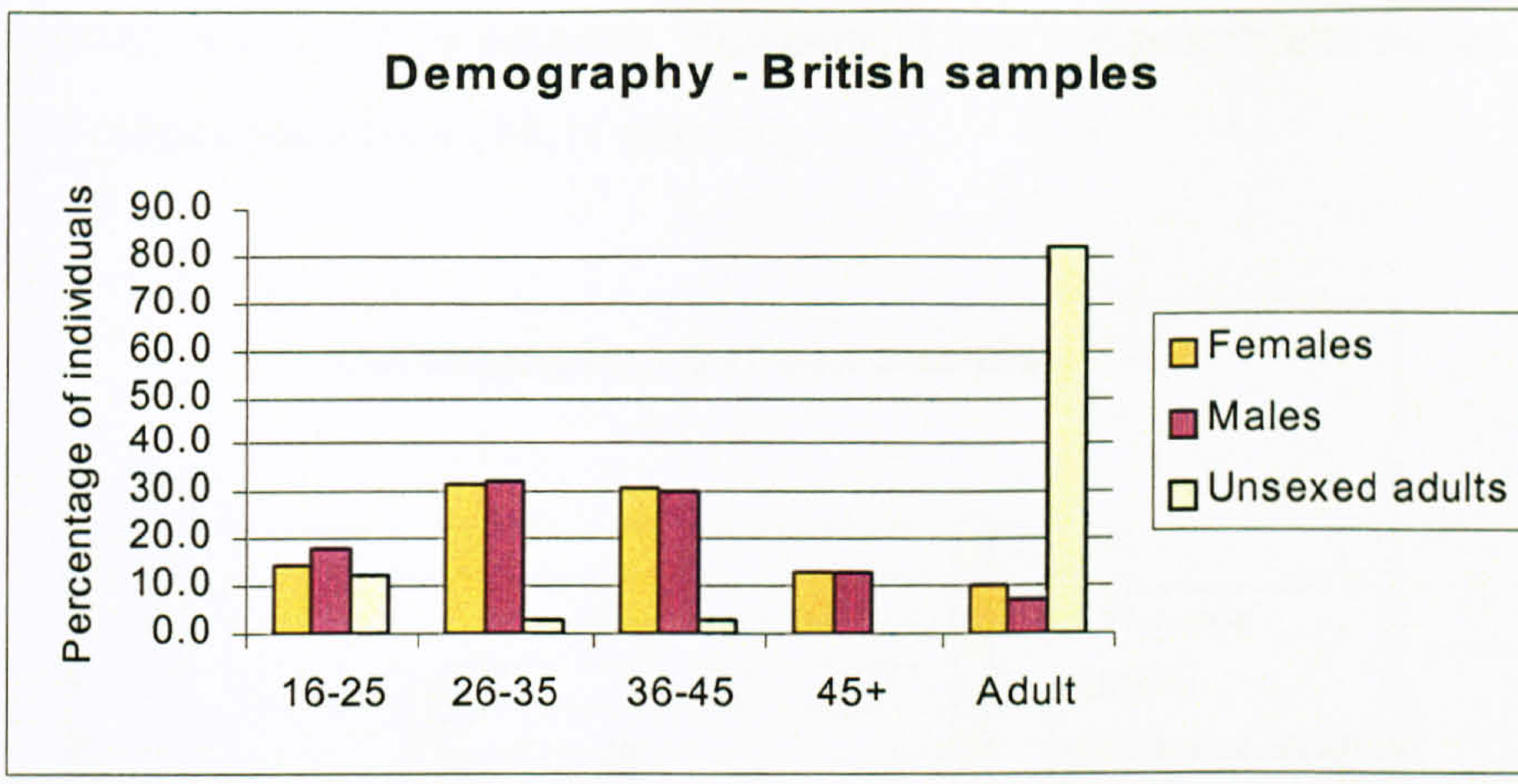


Fig. 5.1.1 Pooled British samples – adult demography.

	<16	16-25	26-35	36-45	45+	Adult	Total
Subadults	**84**						**84** 16.97
Females % %*		**21** 11.05 47.73	**88** 46.32 63.77	**47** 24.74 45.63	**15** 7.9 34.88	**19** 10.0 22.89	**190** 46.23
Males % %*		**17** 10.43 38.64	**48** 29.45 34.78	**54** 33.13 52.43	**28** 17.18 65.12	**16** 9.82 19.28	**163** 39.66
N/D % %*		**6** 10.34 13.64	**2** 3.45 1.45	**2** 3.45 1.94	0	**48** 82.76 57.83	**58** 14.11
Total %*	**84** 16.97	**44** 10.71	**138** 33.58	**103** 25.06	**43** 10.46	**83** 20.2	**495** **(411)**

Table 5.1.8 Demographic profile of pooled German samples (%=percentage within row, %*=percentage within column, %**=percentage within age class in relation to all adults, N/D=adults of undetermined sex, ()=number of adult individuals).

A summary of the sex and age distribution for pooled German samples can be found in Table 5.1.8 and Fig. 5.1.2. Less than one-fifth of the 495 German skeletons were classified as non-adults (16.97 percent), a number significantly below the assumed 33 percent (χ^2=59.6455, p=0.0000, d.f.=1). Among the 411 adult skeletons, more females than males were present (females: 46.23 percent, males: 39.66 percent). However, this difference was statistically insignificant (χ^2=2.0652, p=0.1507, d.f.=1). Fifty-eight adult skeletons could not be assigned to any sex (14.11 percent). Most individuals died in young-middle adult age and in this category a high proportion were women (46.32 percent). Men died most often as middle-aged adults (33.13 percent). The age classes with the fewest number of individuals were the young and old adult categories. The distribution between the sexes was comparatively balanced for young adults (females: 11.05 percent, males: 10.4 percent), but six individuals in this age class could not be sexed. Among old adults, markedly more males than females were found (females: 7.9

percent, males: 17.18 percent). However, it was not possible to assign an age and/or sex to a number of adults (14.11 percent).

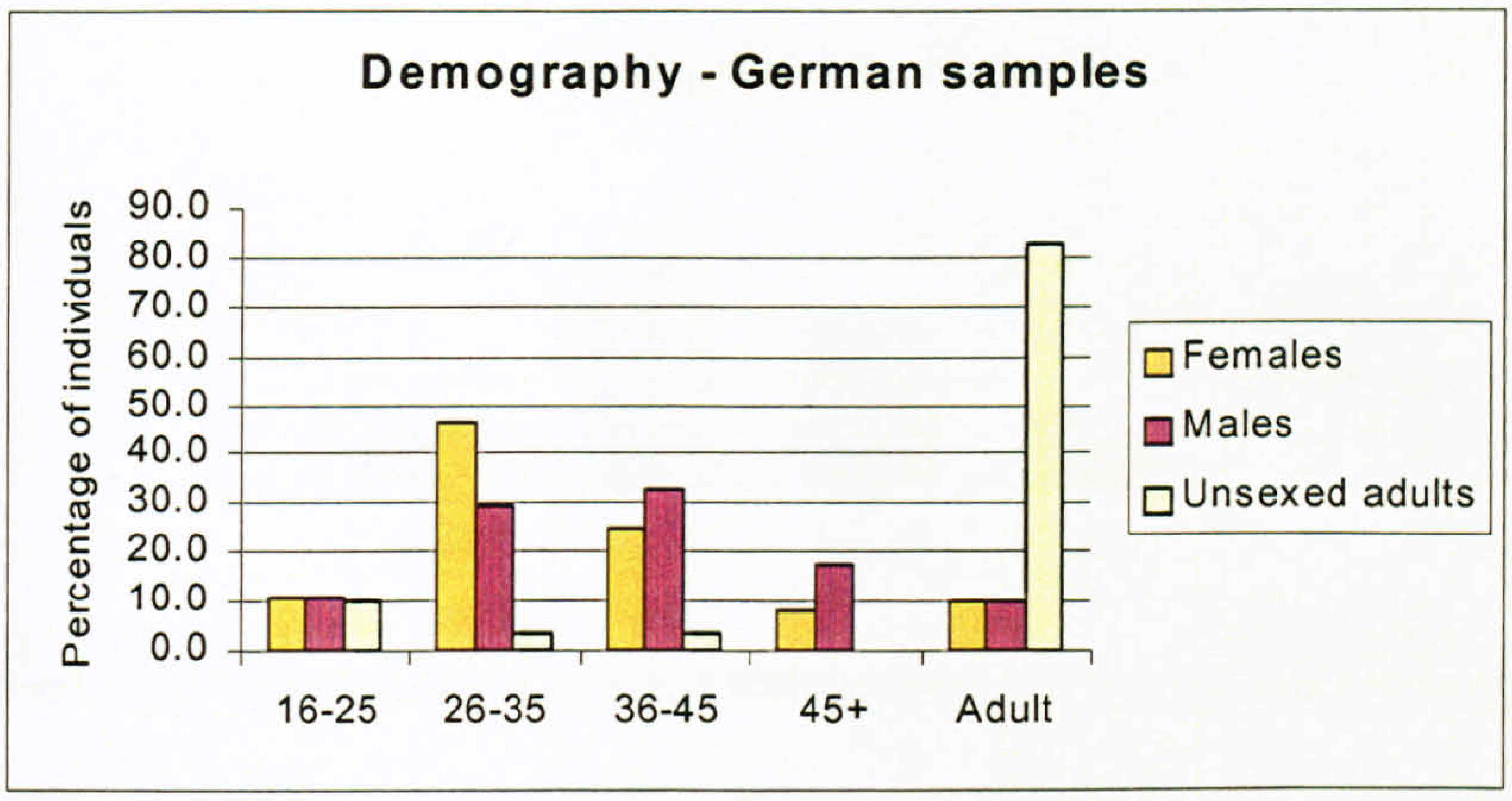


Fig. 5.1.2 Pooled German samples – adult demography.

Fig. 5.1.3 compares the sex distribution between the two pooled samples, as well as the proportion of non-adults. Clearly more non-adults were found in the combined British samples (27.25 percent) than in the German samples (16.97 percent). In both countries, women were present in equal proportion (British females: 46.67 percent, German females: 46.23 percent). British males were less often found than German males, although the difference was marginal (British males: 32.38 percent, German males: 39.66 percent). More British than German individuals could not be assigned to either sex (British individuals: 20.95 percent, German individuals 14.11 percent).

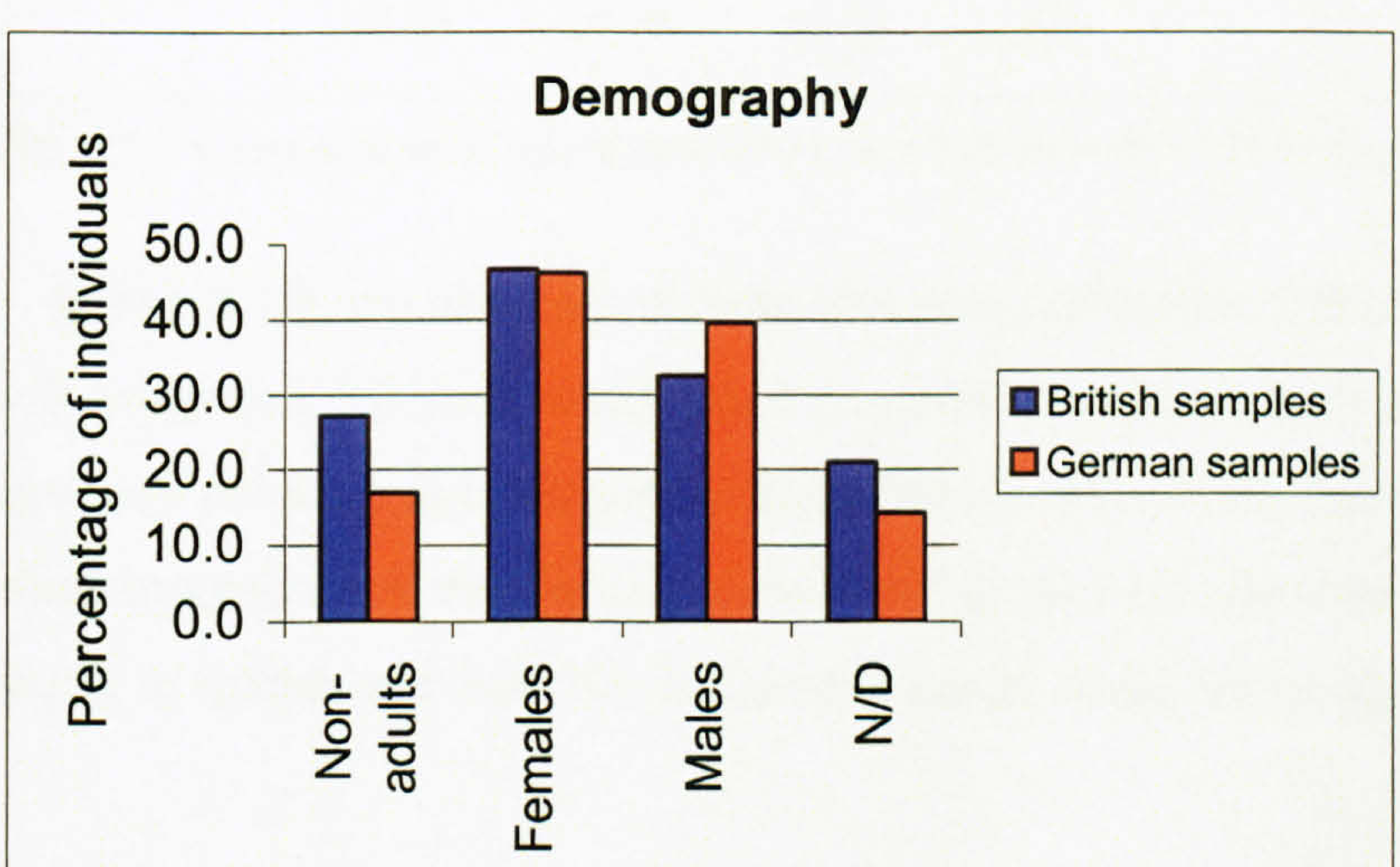


Fig. 5.1.3 Sex distribution of pooled samples (N/D=adults of undetermined sex).

Fig. 5.1.4 provides an age-specific comparison for British and German females. Slightly more British women were present in the young, middle-aged and old adult age classes, although the differences in each case were not marked. However, a much higher proportion of German females were classified as young-middle adults.

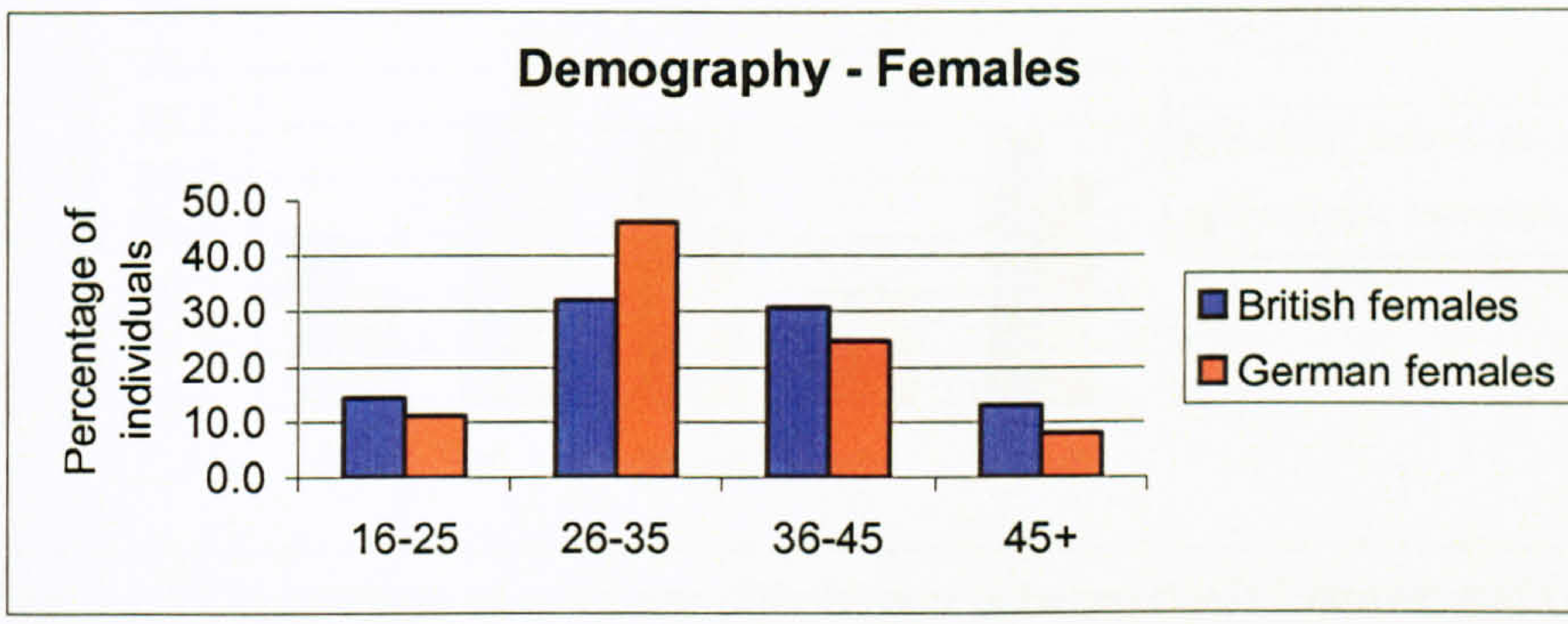


Fig. 5.1.4 Comparison of age distribution between British and German females.

The age-specific distribution among British and German males can be seen in Fig. 5.1.5. Slightly more British men were present in the young and young-middle adult age classes. However, more German men were found in the middle-aged and old adult categories. Nevertheless, these differences were only marginal.

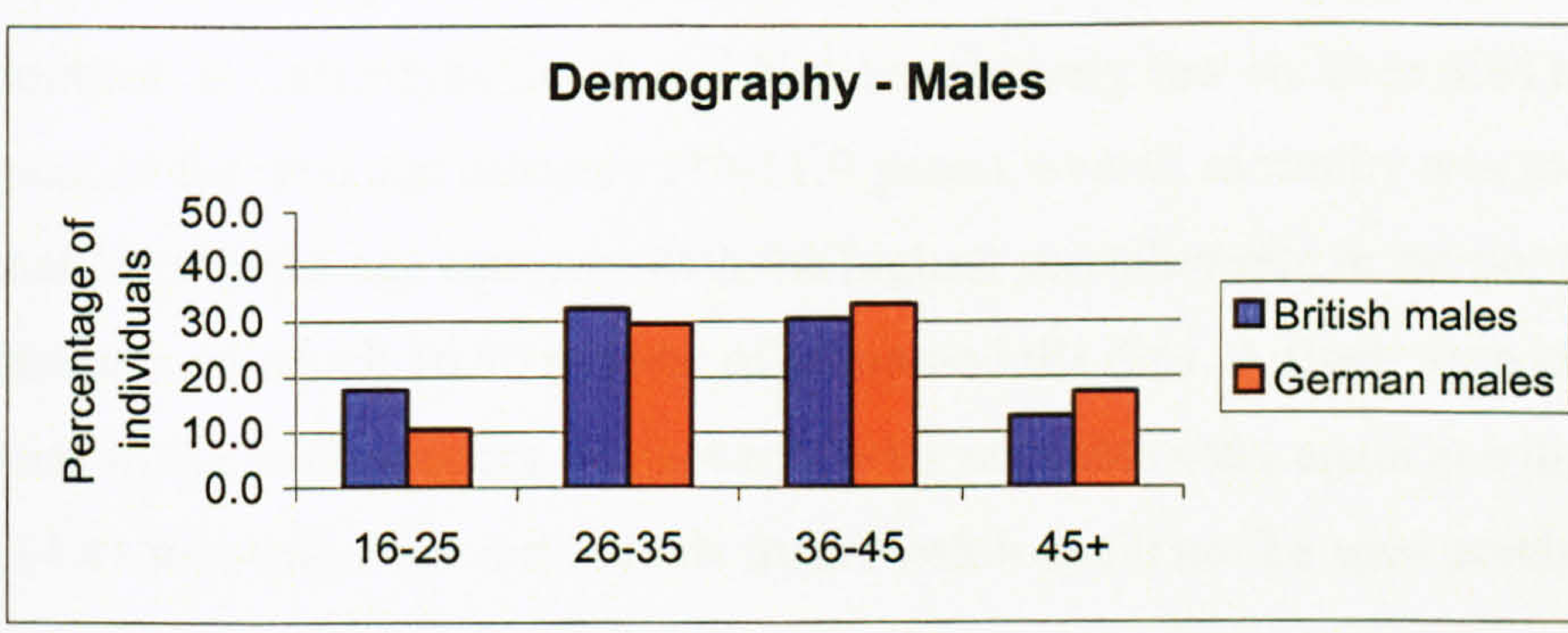


Fig. 5.1.5 Comparison of age distribution between British and German males.

In Fig. 5.1.6, the adult age distribution between pooled British and German samples was compared. Approximately equal numbers of individuals were found in the middle-aged and old adult age categories. More British individuals had died as young adults, while more German individuals were found in the next age class. However, almost one-fourth of British and one-fifth of German adults could not be aged more accurately.

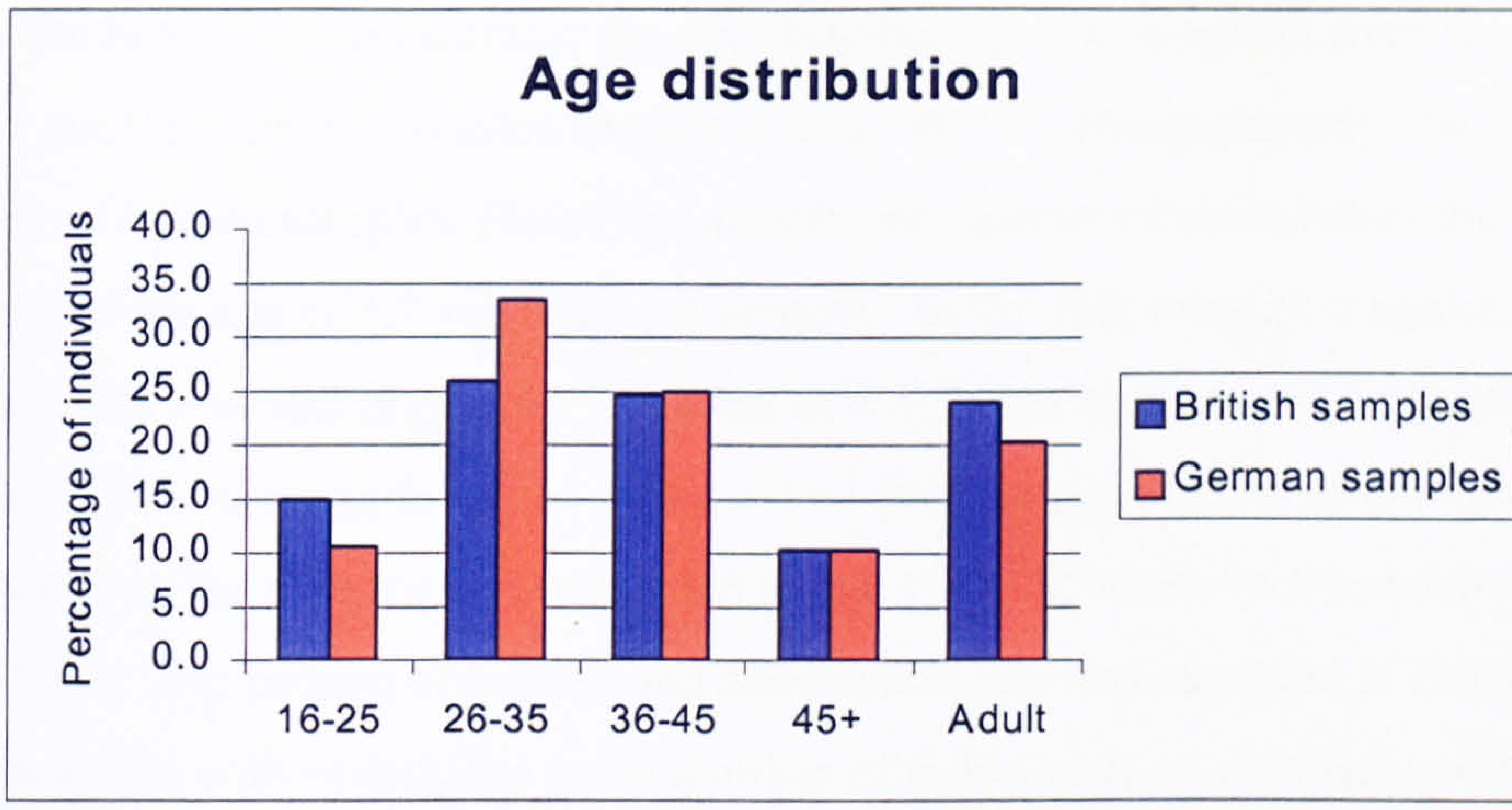


Fig. 5.1.6 Comparison of adult age distribution between pooled British and German samples.

Non-adult age distribution for the three British samples, as well as pooled results can be seen in Table 5.1.9. More than 15 percent of all individuals died before they reached their first year (15.25 percent). At Castledyke South, the percentage of very young children was especially high (23.91 percent). The overall percentage of children's deaths was lower in the next four age categories, each spanning two years. However, at Apple Down, high mortality rates were reached between the age of 1 and 5.9 years. In contrast, at Castledyke South and Norton relatively few children died before their tenth year. In the next age category (10-11.9 years), overall mortality was more than doubled, making this the age category with the highest mortality rate in the pooled British samples, in which 16.95 percent of all non-adults died. A sharp drop to 7.63 percent was seen in the next category. However, 14-16 year-olds were again at a high risk of death (14.41 percent). Four individuals from Norton could not be aged precisely, because of poor preservation.

Age category (years)	Apple Down		Castledyke South		Norton		Total	
	N	%	N	%	N	%	N	%
-0.9	4	13.79	11	23.91	3	6.98	18	15.25
1-1.9	3	10.34	3	6.52	3	6.98	9	7.63
2-3.9	4	13.79	3	6.52	1	2.33	8	6.78
4-5.9	5	17.24	3	6.52	4	9.3	12	10.17
6-7.9	2	6.9	4	8.7	6	13.95	12	10.17
8-9.9	2	6.9	3	6.52	4	9.3	9	7.63
10-11.9	4	13.79	9	19.57	7	16.28	20	16.95
12-13.9	1	3.45	4	8.7	4	9.3	9	7.63
14-15.9	4	13.79	6	13.04	7	16.28	17	14.41
Child	0	0.0	0	0.0	4	9.3	4	3.39
Total	29	100.0	46	100.0	43	100.0	118	100.0

Table 5.1.9 Non-adult age distribution for British sites and pooled British samples (N=number of individuals present, Child=non-adult without more precise age estimate).

Table 5.1.10 demonstrates the age distribution of non-adults from German sites and the pooled German samples. Before the age of two, comparatively few individuals died in the German samples. However, almost one-quarter of all children did not survive beyond the age of 3.9 years (22.62 percent). In the following two age categories, mortality was still high (14.29 percent of 4-5.9 year olds and 13.1 percent of 5-6.9 year olds). This rise was followed by a marked decline in mortality to 4.76 percent. However, the next increase occurred at age 10-11.9, when 14.29 percent failed to survive. The pattern of decline and subsequent rise was repeated in the next two age categories with exactly the same number of individuals as previously described.

Age category (years)	Neresheim		Nusplingen		Pleidelsheim		Total	
	N	%	N	%	N	%	N	%
-0.9	2	5.88	1	5.0	0	0.0	3	3.57
1-1.9	3	8.82	2	10.0	2	6.67	7	8.33
2-3.9	8	23.53	4	20.0	7	23.33	19	22.62
4-5.9	5	14.71	3	15.0	4	13.33	12	14.29
6-7.9	5	14.71	2	10.0	4	13.33	11	13.1
8-9.9	1	2.94	3	15.0	0	0.0	4	4.76
10-11.9	5	14.71	1	5.0	6	20.0	12	14.29
12-13.9	1	2.94	1	5.0	2	6.67	4	4.76
14-15.9	4	11.76	3	15.0	5	16.67	12	14.29
Child	0	0.0	1	5.0	0	0.0	0	0.0
Total	34	100.0	20	100.0	30	100.0	84	100.0

Table 5.1.10 Non-adult age distribution for German sites and pooled German samples (N=number of individuals present, Child=non-adult without more precise age estimate).

A comparison between British and German non-adult mortality rates is displayed in Fig. 5.1.7. There are huge discrepancies in the youngest age category, where more than three times more British non-adults were present. Between the age of 1-1.9 years, almost the same number of non-adults in both pooled samples had died. However, a striking increase in German non-adult mortality occurred between the age of 2-3.9 years, although this was not matched in the British children, who showed a slightly lower rate compared to the previous age category. Between the ages of 4-5.9 and 6-7.9 years, mortality rates of British and German children were approximating one another, only to follow a similar pattern of decline and rise in the remaining four age categories.

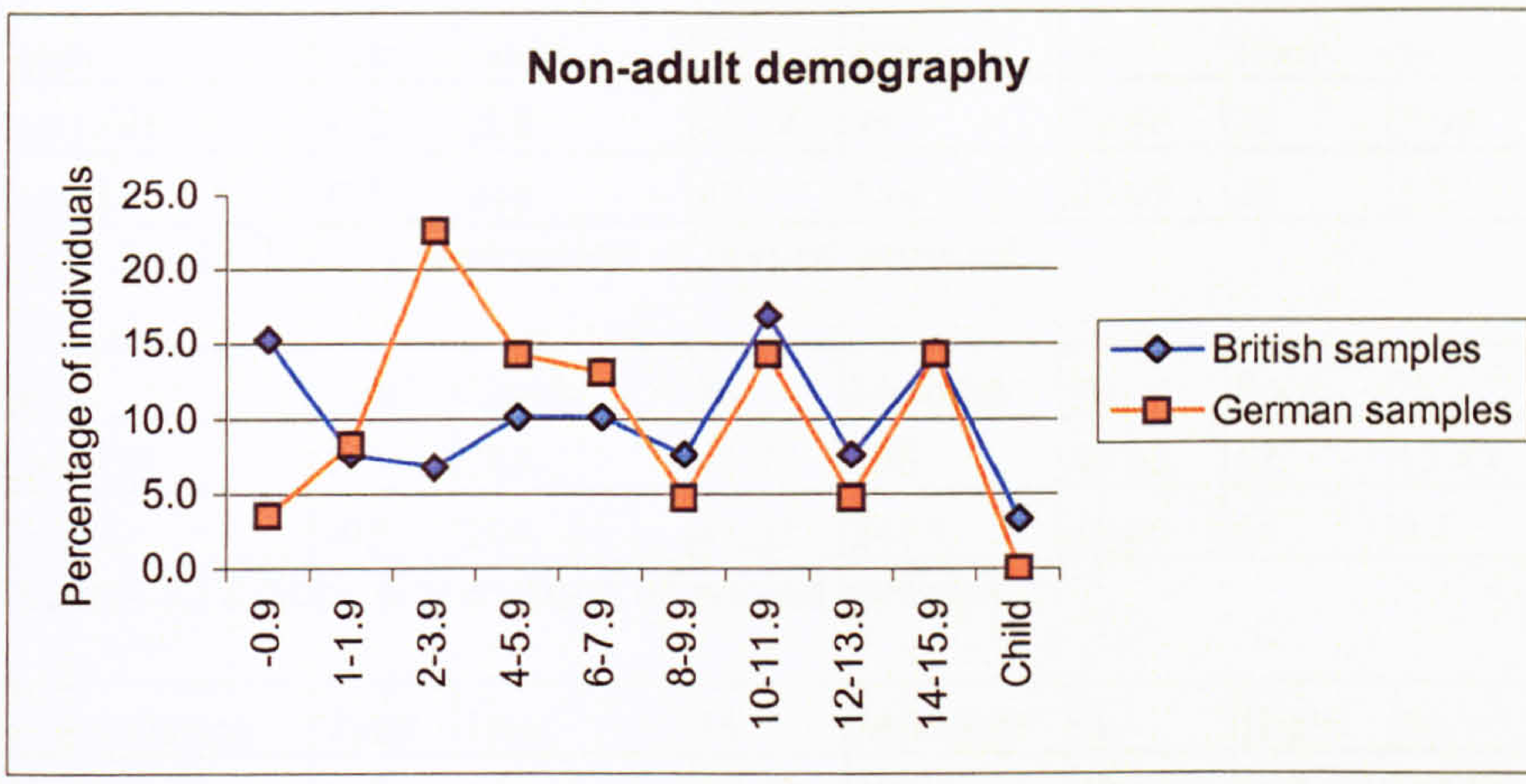


Fig. 5.1.7 Non-adult demography for pooled British and German samples.

5.1.1 Preservation

The preservation of teeth and bones will not only influence the assessment of demographic parameters, it also dictates which disease categories are likely to be found. For instance, in populations with poorly preserved dental remains, the assessment of dental disease will be seriously compromised. Detailed data for the preservation of bones and teeth can be found on CD-ROM, Appendix C1 'Demographic structure'. Results for pooled samples sub-divided into four general preservation categories outlined in Chapter Four (4.2.2 Preservation) are presented here. Table 5.1.11 compares tooth preservation of pooled British and German individuals. In both countries, almost half of all individuals had well preserved teeth and only a few individuals had teeth that were poorly preserved. However, almost one-quarter of all British individuals had no dental remains. Table 5.1.12 compares bone preservation between the two samples. In both, the majority of skeletons were found to have good or medium bone preservation. Only a few individuals in both countries displayed a low percentage of skeletal fragmentation (Table 5.1.13). In the pooled German samples, more individuals showed moderate fragmentation, whereas more British skeletons were highly fragmented. The most noticeable differences between the two samples were found when skeletal completeness was compared (Table 5.1.14). Almost one-quarter of all British individuals had a recovery rate higher than 75 percent, but less than 10.0 percent of German samples were more than 75 percent complete. Poor skeletal completeness (less than 25 percent) was found in approximately one-fifth of British and more than one-quarter of German individuals. Nevertheless, the majority of individuals in both countries were partially preserved (between 25 and 75 percent).

Tooth	Total	Good	%	Medium	%	Poor	%	Absent	%
Total GB	433	208	48.04	99	22.86	22	5.08	104	24.02
Total D	495	246	49.7	144	29.09	26	5.25	79	15.96

Table 5.1.11 Tooth preservation of pooled samples.

Bone	Total	Good	%	Medium	%	Poor	%	Absent	%
Total GB	433	185	42.73	176	40.65	67	15.47	5	1.15
Total D	495	204	41.21	241	48.69	48	9.7	2	0.4

Table 5.1.12 Bone preservation of pooled samples.

Fragmentation	Total	Low	%	Moderate	%	High	%	Absent	%
Total GB	433	68	15.70	173	39.95	187	43.19	5	1.15
Total D	495	96	19.39	297	60.0	100	20.2	2	0.4

Table 5.1.13 Skeletal fragmentation of pooled samples.

Completeness		Complete	%	Partial	%	Poor	%	Absent	%
Total GB	433	100	23.09	239	55.2	89	20.55	5	1.15
Total D	495	42	8.48	320	64.65	131	26.46	2	0.4

Table 5.1.14 Skeletal completeness of pooled samples.

The difference between skeletal completeness in the two study samples warranted a closer investigation and Figs. 5.1.8 (British samples) and 5.1.9 (German samples) present the previous data by sex. British females, males and non-adults in the British samples had consistently better skeletal completeness than their German counterparts. Only adults of undetermined sex had similarly poor skeletal completeness across the countries.

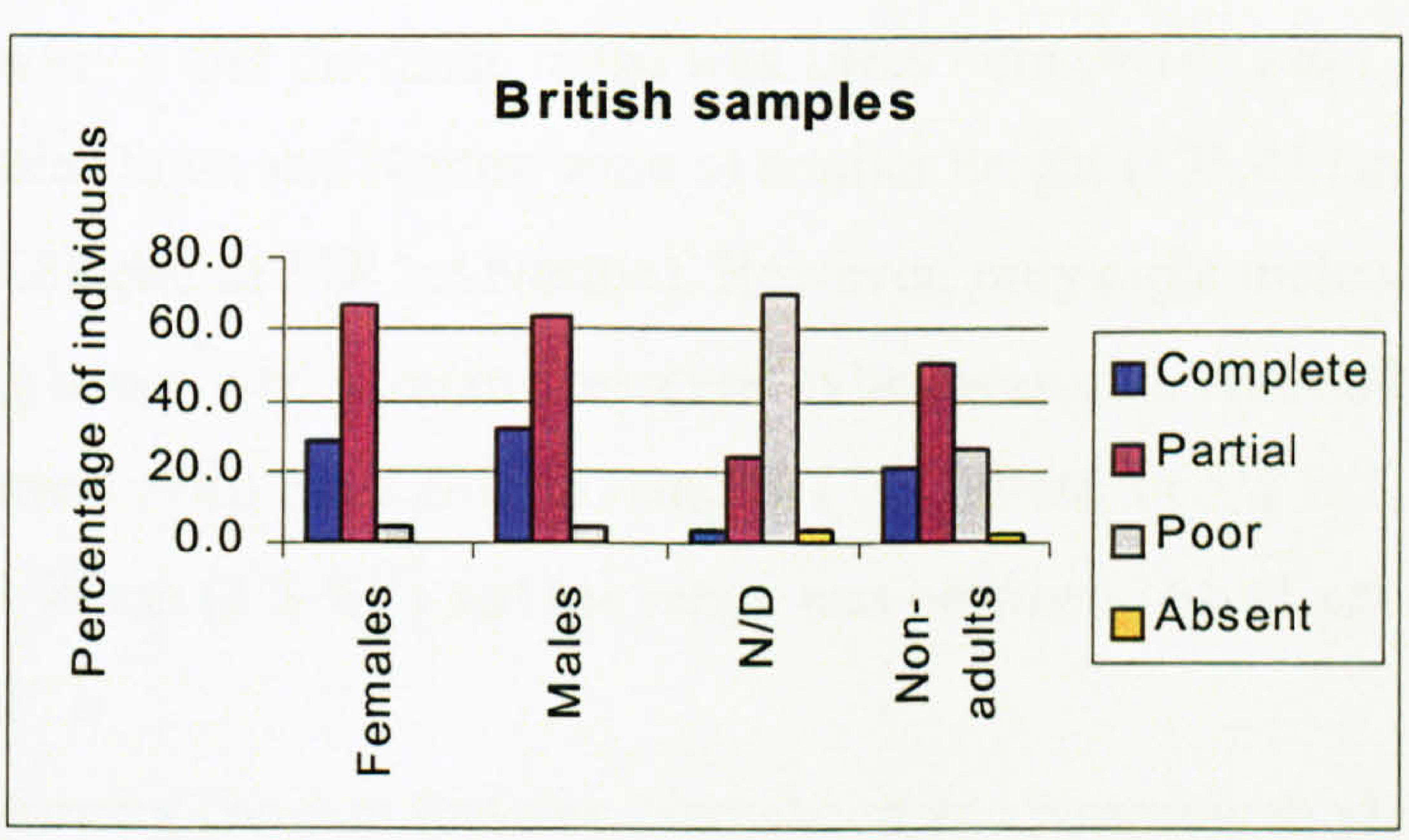


Fig. 5.1.8 Skeletal completeness of British samples.

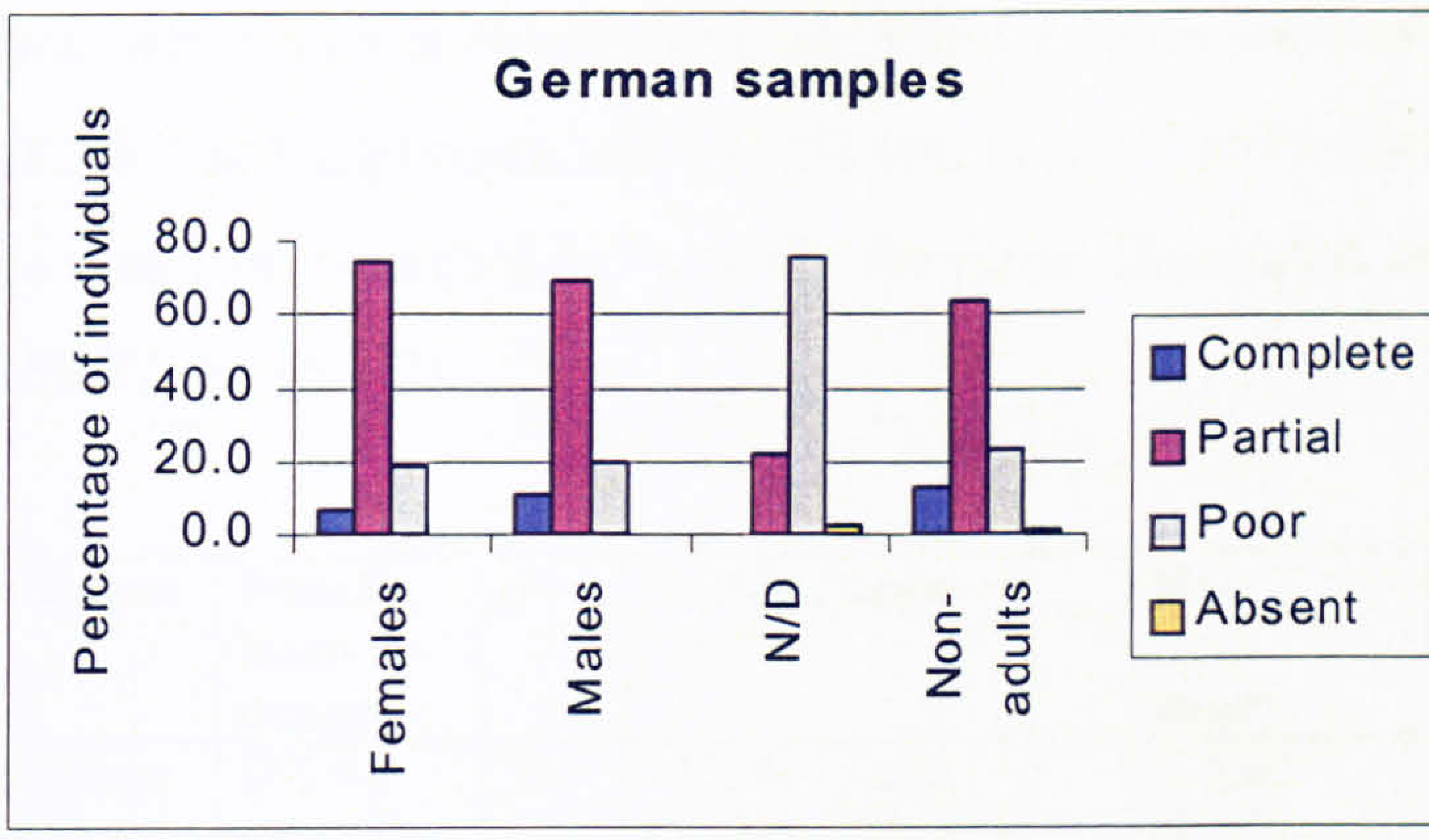


Fig. 5.1.9 Skeletal completeness of German samples.

5.2 Stature estimation

Individual long bone measurements and stature estimation for each adult female and male individual can be found on CD-ROM, Appendix C2 'Long Bone Measurements'.

5.2.1 Adult stature

Table 5.2.1 tabulates adult female and male stature for the three British and German study samples. Among British sites, women were tallest at Norton (165.36 cm, or 5'5''), while females from Apple Down and Castledyke South were of equal height (161.91 cm, or 5'4'' at Apple Down and 161.72 cm, or 5'4'' at Castledyke South). However, the number of women from Norton for whom measurements were possible was lower than at the other two British sites. The overall mean stature was 163.0 cm (5'4 ½''), and the mean range was 148.97 cm (4'10'') to 179.55 cm (5'11''). Men from Apple Down and Norton were of similar height (175.43 cm, or 5'9'' at Apple Down and 174.88 cm, or 5'9'' at Norton). However, only eight male individuals from Norton had long bones well enough preserved to be measured. At Castledyke South, men were the shortest of all three British samples (171.66 cm, or 5'7 ½''). Overall male stature was 173.99 cm (5'8 ½'') and the range was between 161.41 cm (5'4'') and 185.88 cm (6'1'').

Among German females, Neresheim and Nusplingen yielded similar mean heights with 163.25 cm (5'4 ½'') and 163.27 cm (5'4 ½''), respectively. At Pleidelsheim, females were slightly shorter at 161.1 cm (5'4''). Overall mean height was 162.54 cm (5'4 ½''). Female height ranged from as short as 145.5 cm (4'9'') to as tall as 177.47 cm (5'10''). Men at Neresheim were the tallest (176.35 cm, or 5'9 ½'') of all German samples, while men at Nusplingen and Pleidelsheim were of a similar height (173.27 cm, or 5'8" at Nusplingen and 173.58 cm, or 5'8" at Pleidelsheim). The overall mean stature was 174.4 cm (5'8 ½"), while the range fluctuated between 157.02 cm (5'2") and 189.93 cm (6'3").

Adult Stature	Female mean stature	n=	Female Range	Male mean stature	n=	Male range
Apple Down	161.91 (5'4")	39	152.59-171.43 (5'-5'7 ½")	175.43 (5'9")	29	165.6-188.09 (5'5"-6'2")
Castledyke South	161.72 (5'4")	39	148.97-179.55 (4'10"-5'11")	171.66 (5'7 ½")	32	161.41-185.88 (5'4"-6'1")
Norton	165.36 (5'5")	16	150.64-176.12 (4'11"-5'9 ½")	174.88 (5'9")	8	169.24-181.6 (5'6 ½"-5'11 ½")
Total GB	163.0 (5'4 ½")	94	148.97-179.55 (4'10"-5'11")	173.99 (5'8")	69	161.41-188.09 (5'4"-6'2")
Neresheim	163.25 (5'4 ½")	41	150.5-177.22 (4'11"-5'10")	176.35 (5'9 ½")	31	165.01-189.93 (5'5"-6'3")
Nusplingen	163.02 (5'4 ½")	36	150.5-175.21 (4'11"-5'9")	173.27 (5'8")	34	161.85-184.69 (5'4"-6' ½")
Pleidelsheim	161.1 (5'4")	44	145.5-177.47 (4'9"-5'10")	173.51 (5'8")	37	157.02-184.69 (5'2"-6' ½")
Total D	162.46 (5'4 ½")	121	145.53-177.47 (4'9"-5'10")	174.38 (5'8 ½")	102	157.02-189.93 (5'2"-6'3")

Table 5.2.1 Mean adult stature by sex and site in centimetres and feet and inches (n=number of individuals, Total GB =pooled British samples, Total D =pooled German samples).

Skeletal element	AP	CS	NT	Female total	Female +/-	AP	CS	NT	Male total	Male +/-	Total
	n	n	n			n	n	n			
Femur + tibia	27	27	10	64	3.55	23	16	4	43	2.99	107
Femur	6	3	3	12	3.72	3	4	2	9	3.27	21
Tibia	2	3	0	5	3.66	2	8	1	11	3.37	16
Fibula	1	1	0	2	3.57	0	2	0	2	3.29	4
Humerus	0	1	2	3	4.45	0	1	1	2	4.05	5
Radius	3	3	1	7	4.24	1	1	0	2	4.32	9
Ulna	0	1	0	1	4.30	0	0	0	0	4.32	1
Total	39	39	16	94		29	32	8	69		163

Table 5.2.2 Breakdown of number of skeletal elements used for adult stature calculation in pooled British samples (+/- = standard deviation) (AP=Apple Down, CS=Castledyke South, NT=Norton).

Table 5.2.2 provides information on the number of long bones used to calculate adult stature for British samples. Combined femur and tibia measurements were employed most often and these two bones provide the lowest possible standard deviation when using Totter and Gleser's regression formulae (Trotter, 1970). A large proportion of female stature calculations were based on combined femur and tibia length (68.09

percent), while 62.32 percent of male stature calculations used these two long bones. In total, 65.64 percent of all measurements were taken on the combined femur and tibia length.

Skeletal element	NE	NU	PL	Female	Female +/-	NE	NU	PL	Male	Male +/-	Total
	n	n	n	total		n	n	n	total		
Femur + tibia	16	23	26	65	3.55	12	23	26	61	2.99	126
Femur	8	4	11	23	3.72	10	3	5	18	3.27	41
Tibia	7	7	5	19	3.66	2	6	3	11	3.37	30
Fibula	0	0	0	0	3.57	0	0	1	1	3.29	1
Humerus + tibia	3	0	0	3	3.67	0	0	0	0	3.58	3
Humerus	1	1	1	3	4.45	3	0	0	3	4.05	6
Radius	6	1	1	8	4.24	2	2	2	6	4.32	14
Ulna	0	0	0	0	4.30	2	0	0	2	4.32	2
Total	41	36	44	121		31	34	37	102		223

Table 5.2.3 Breakdown of number of skeletal elements used for adult stature calculation in pooled German samples (+/- = standard deviation) (NE=Neresheim, NU=Nusplingen, PL=Pleidelsheim).

Skeletal elements used to calculate stature for German adults are listed in Table 5.2.3. Slightly more than half of all female stature calculations (53.72 percent) were based on combined femur and tibia length, while 59.8 percent of male height was calculated using these two bones. In total, 56.5 percent employed this bone combination with the lowest standard deviation. However, the percentage was lower than the one achieved for pooled British samples.

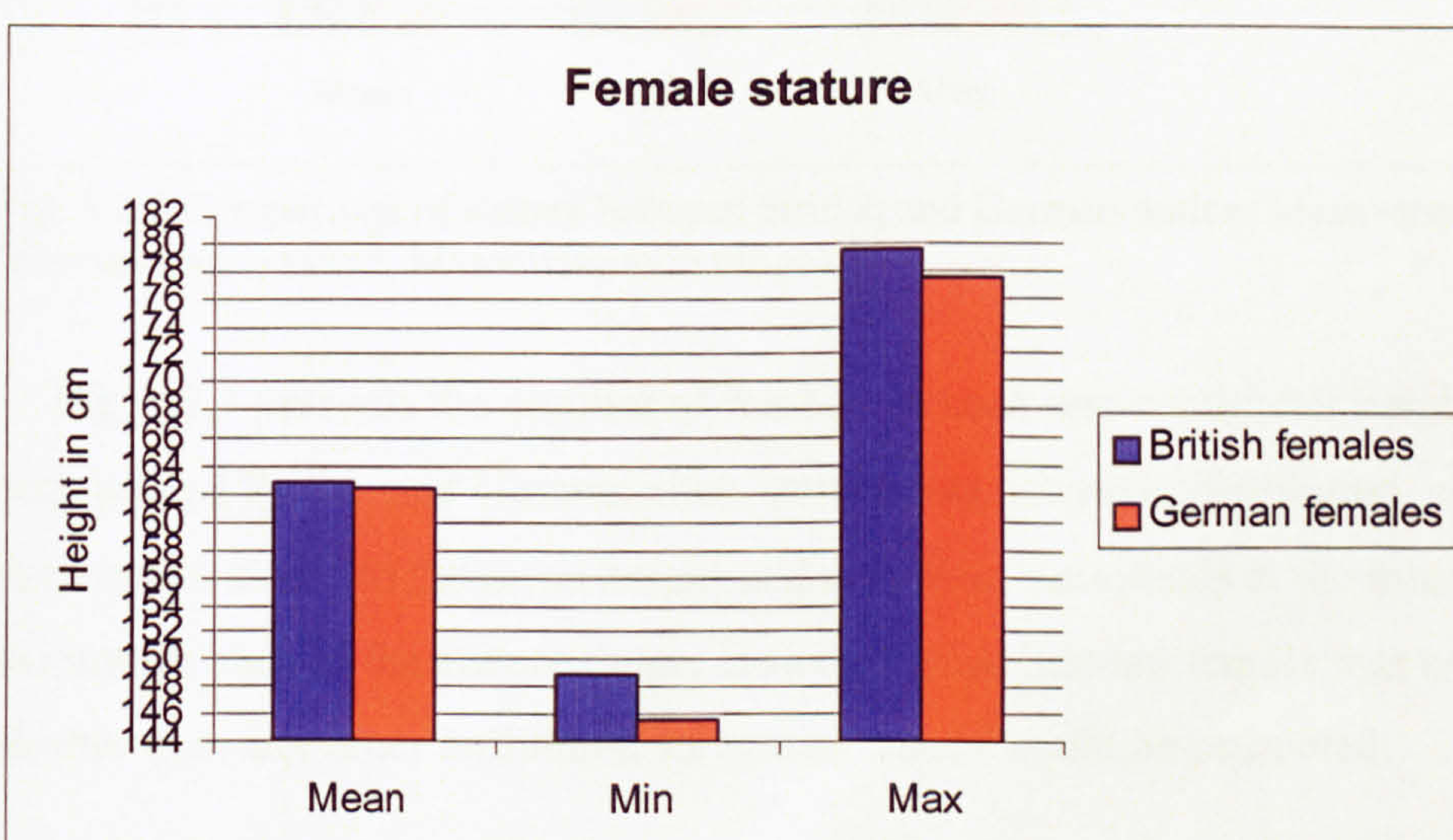


Fig. 5.2.1 Comparison of stature between British and German females (Mean=mean stature, Min=minimum range, Max=maximum range).

Pooled sample means for female stature, as well as their respective minimum and maximum range are presented in Fig. 5.2.1. German females are marginally shorter than their British counterparts. However, the difference was only 54 millimetres or approximately one-fifth of an inch. Equally, the range found for German females was comparable to British results, although German females had a shorter lower and a slightly higher upper limit compared to British females.

British and German mean male height was approximately the same, with German males being only 39 mm taller than British males (Fig. 5.2.2). However, the mean minimum of male stature range with 161.29 cm (5'3 ½'') was lower for German samples, compared to 165.41 cm (5'5'') found for British males. Nevertheless, the upper mean range with 185.19 cm (6'1'') for British males and 186.44 cm (6'1 ½'') for German males was similar.

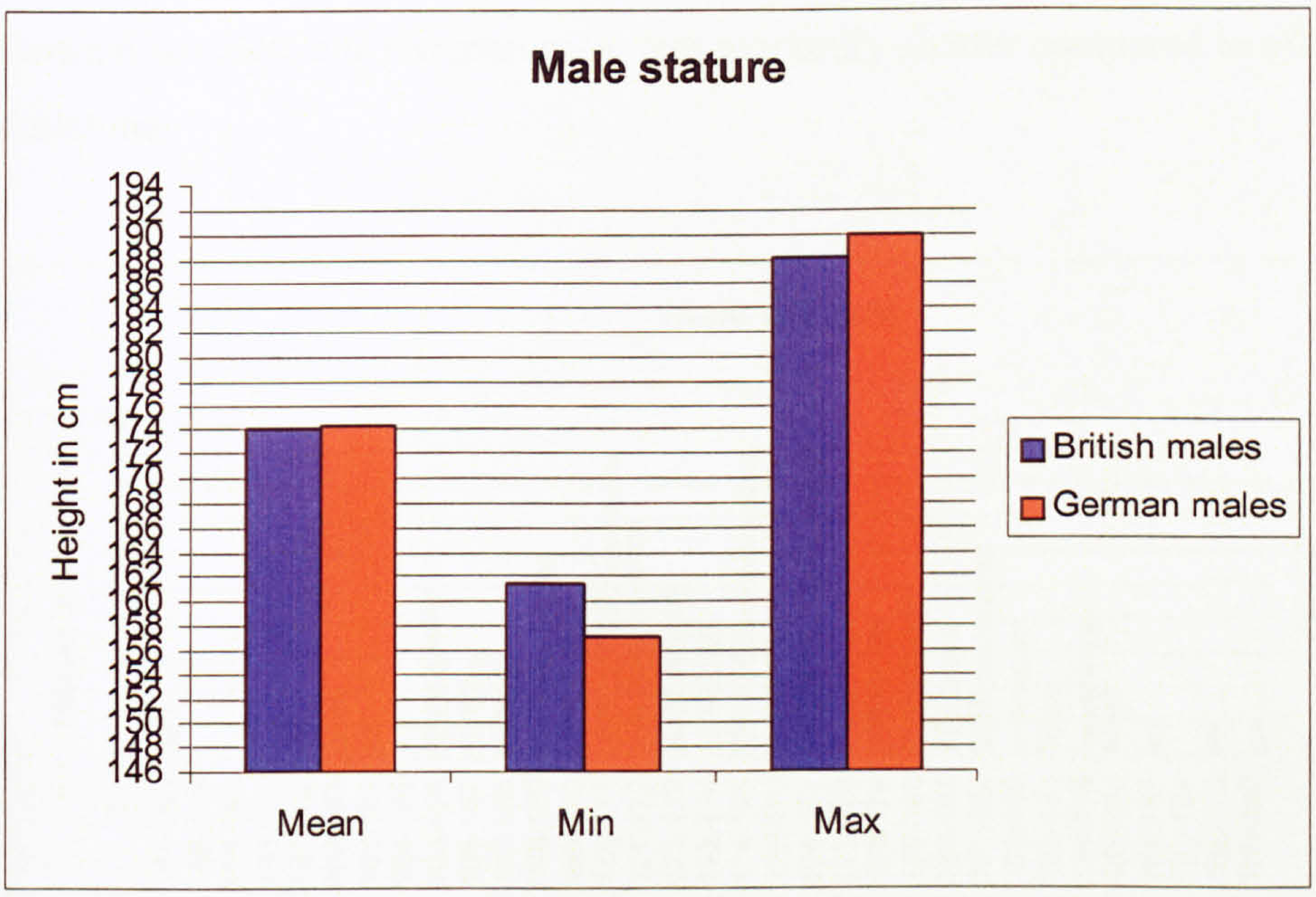


Fig. 5.2.2 Comparison of stature between British and German males (Mean=mean stature, Min=minimum range, Max=maximum range).

Fig. 5.2.3 presents the number of females in each one-centimeter height class. For both pooled British and German sites, stature was normally distributed, with more individuals closer to the mean height and only few individuals at the minimum and maximum ends of the stature range. However, one German female was noticeably shorter than any other individual for whom stature could be estimated.

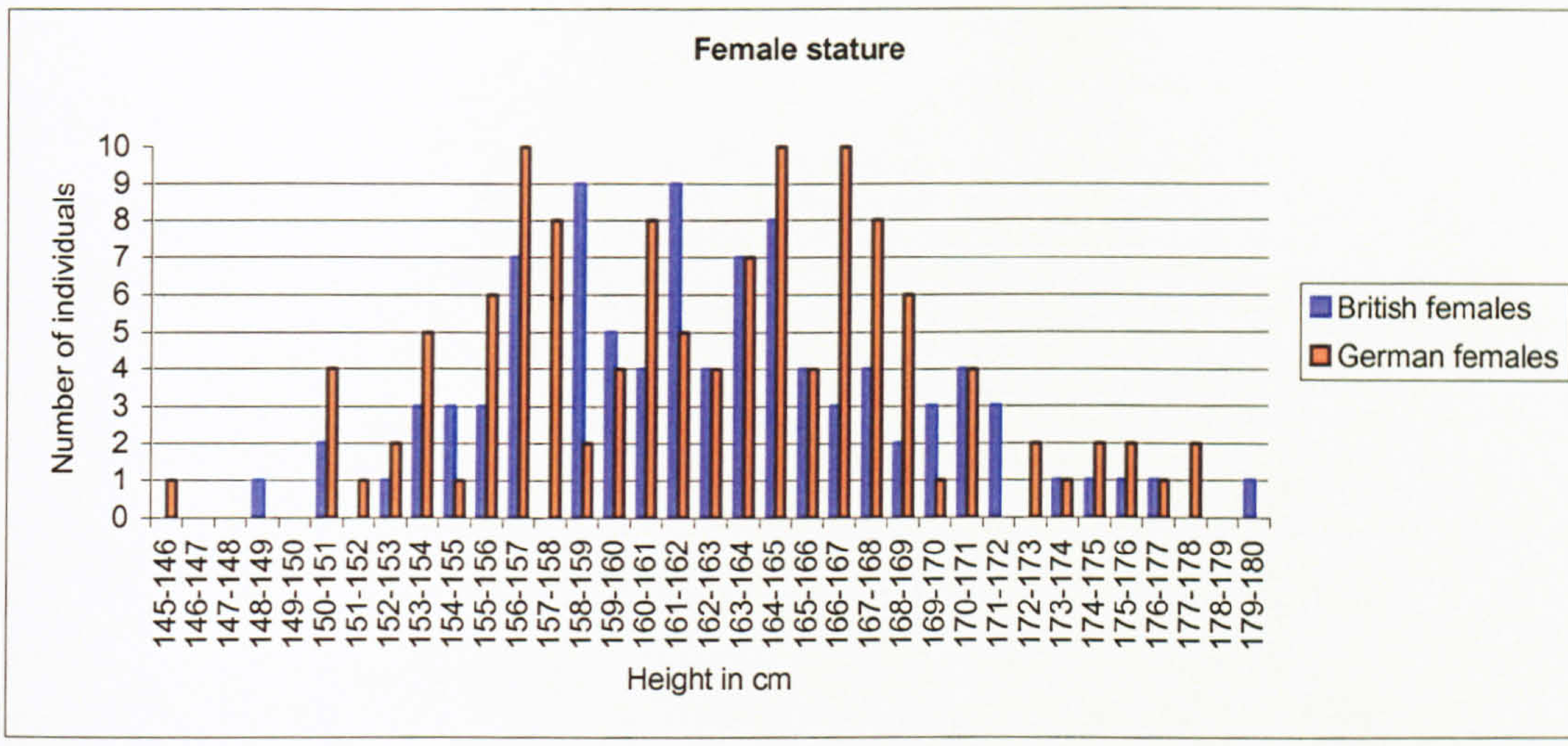


Fig. 5.2.3 Comparison of female height distribution for pooled British and German samples.

Height distribution of male individuals is displayed in Fig. 5.2.4. Again, the stature of most individuals was concentrated around the middle of the entire range. As seen for German females, one German male was markedly shorter compared to other male skeletons.

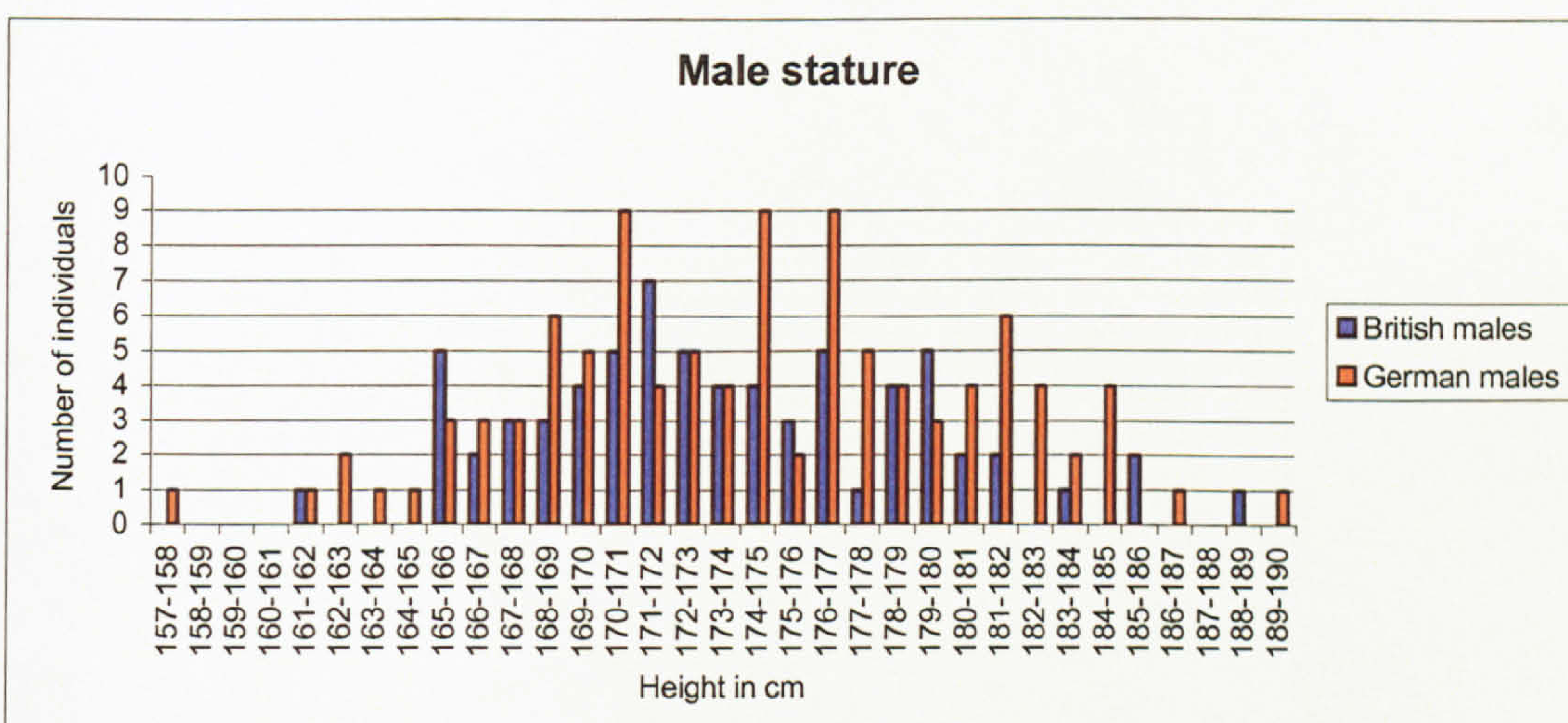


Fig. 5.2.4 Comparison of male height distribution for pooled British and German samples.

5.2.2 Non-adult growth profiles

Table 5.2.4 and Fig. 5.2.5 demonstrate differences in age-related femoral length for pooled samples of non-adult individuals. Thirty-nine British and 24 German skeletons who were estimated to be under the age of 16 years had both parameters – dental age and femoral length – assessable. British non-adults showed a relatively steady linear increase in femoral length with age, with the exception of individuals falling into the 8-

9 year age class, where femoral length dropped slightly compared to the previous age class. German non-adult femur measurements followed a less predictable pattern. Here, 6-7 year-olds had shorter femora than individuals in the preceding age class and the same was found when 10-11 year-olds were compared to their next youngest peers. Furthermore, some discrepancies between non-adult British and German femur length within the age classes were noticed. This was most striking at age 5-6 years, when German individuals were 4.63 cm taller than their British counterparts. The contrary was observed in the next oldest age class; here, English non-adults had gained 3.2 cm compared to German skeletons. After the age of seven years femur measurements were more uniform between the two study samples. However, the number of individuals per age class was low, five being the highest number of femora in any age class, which does not provide a sound statistical basis.

	British samples		German samples	
Age class	n	Femur length (cm)	n	Femur length (cm)
0-1	5	8.8	0	NA
1-2	5	11.35	1	12.5
2-3	1	17.5	5	16.86
3-4	0	**18.73**	1	16.5
4-5	0	**19.96**	1	19
5-6	4	22.4	3	27.03
6-7	4	25.05	2	21.85
7-8	1	29	2	29.75
8-9	2	27.05	0	**30.03**
9-10	2	28.7	2	30.3
10-11	5	32.5	4	29.58
11-12	2	33.25	1	33.2
12-13	2	37.35	1	37
13-14	0	**38.65**	0	**37.75**
14-15	4	39.95	1	38.8
15-16	2	39.4	0	NA
Total	39		24	

Table 5.2.4 Mean femur diaphyseal length (cm) by dental age class (n= number of femora, NA=measurement not available, **bold** denotes an estimated value).

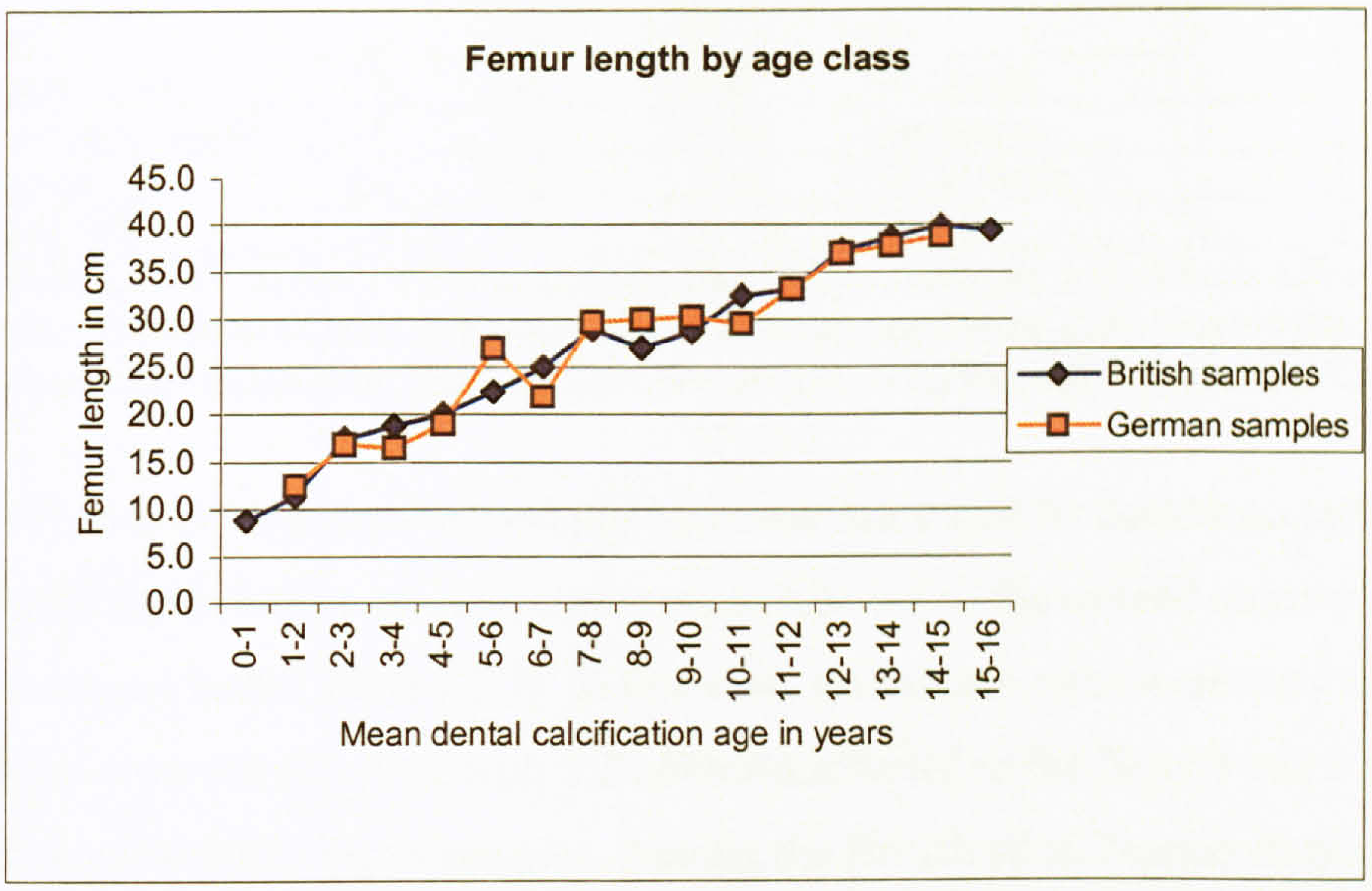


Fig. 5.2.5 Femur diaphyseal length plotted against mean dental calcification age.

5.3 DENTAL DISEASE

All individuals with dental remains are summarized on CD-ROM, Appendix C3 by sample and specific dental disease, providing information on dental caries, calculus, periapical lesions and pulp exposure, ante-mortem tooth loss, periodontal disease and enamel hypoplasia. Keys for dental disease data are listed as 'Appendix C3 Key to …'.

5.3.1 Dental caries

Dental caries – deciduous teeth

Deciduous and permanent teeth were analysed separately for dental caries experience and subsequently the results will be presented separately. Only few non-adult individuals with deciduous teeth were affected by the disease and, as dental caries is age dependent, this comes as no surprise. Results for individual samples by individual count and tooth count method are presented in Tables 5.3.1 and 5.3.2, respectively.

The prevalence for deciduous caries within the British samples by individual skeletons ranged between 10.0 percent for Apple Down to 16.67 percent at Castledyke South and Norton. German individuals showed frequencies ranging from 8.7 percent at Neresheim, 9.09 percent at Nusplingen, to as high as 15.79 percent at Pleidelsheim. Despite the higher caries prevalence for the pooled British samples, the difference between British and German deciduous tooth caries was not significant when applying a chi-squared test (χ^2=0.1189, p=0.7302, d.f.=1).

Site	n	N	%	Site	n	N	%
Apple Down	2	20	10.0	Neresheim	2	23	8.7
Castledyke South	2	12	16.67	Nusplingen	1	11	9.09
Norton	2	12	16.67	Pleidelsheim	3	19	15.79
Total GB	6	44	14.45	Total D	6	53	11.32

Table 5.3.1 Prevalence of dental caries (deciduous teeth) by individuals affected in relation to individuals with at least one tooth observable (n=number of individuals affected, N=number of individuals observable; Total GB=pooled British samples, Total D=pooled German samples).

However, as not all individuals had their full set of 20 deciduous teeth preserved, dental caries rates were also presented in relation to the overall number of observable deciduous teeth (Table 5.3.2). In this case, prevalence rates were very similar between the two pooled samples, with 2.28 percent affected in the British and 2.53 percent affected in the German samples. Among the British sites, Norton displayed the highest caries frequency (4.84 percent), shortly followed by Castledyke South (4.35 percent). Deciduous teeth from Apple Down had a low caries prevalence with 1.42 percent of teeth affected. Within the German sites, Pleidelsheim yet again showed the highest caries frequency (4.31 percent, while subadults at Neresheim and Nusplingen had an almost similar caries experience (Neresheim: 1.11 percent, Nusplingen: 1.16 percent).

Site	n	N	%	Site	n	N	%
Apple Down	2	241	1.42	Neresheim	2	180	1.11
Castledyke South	4	92	4.35	Nusplingen	1	86	1.16
Norton	3	62	4.84	Pleidelsheim	9	209	4.31
Total GB	9	395	2.28	Total D	12	475	2.53

Table 5.3.2 Prevalence of dental caries (deciduous teeth) by teeth affected in relation to observable teeth (n=number of teeth affected, N=number of teeth observable; Total GB=pooled British samples, Total D=pooled German samples).

Despite these similarities, certain subtle differences between the two countries were detected. Table 5.3.3 provides details on which specific tooth was most often affected by caries. In the British samples only molars displayed carious cavities, while in the German samples, additionally to molars, one canine had a carious lesion. Maxillary teeth were more often affected by caries in both countries, but this difference was more marked in the German samples, where only one mandibular tooth was involved. In the British samples, the maxillary second molar was the tooth showing the highest caries prevalence. German individuals had slightly more maxillary first molars affected, but the maxillary second molar was the tooth with the second highest involvement.

	British samples						German samples				
	Maxilla						Maxilla				
Tooth	i^1	i^2	c	m^1	m^2	Tooth	i^1	i^2	c	m^1	m^2
n	0	0	0	2	3	n	0	0	1	5	5
N	29	27	35	48	49	N	23	36	44	73	81
%	0.0	0.0	0.0	4.17	6.12	%	0.0	0.0	2.27	6.85	6.17
	Mandible						Mandible				
n	0	0	0	1	3	n	0	0	0	1	0
N	13	20	28	49	51	N	23	27	38	64	66
%	0.0	0.0	0.0	2.04	5.88	%	0.0	0.0	0.0	1.56	0.0

Table 5.3.3 Prevalence of dental caries (deciduous teeth) for individual teeth by teeth affected in relation to teeth observable (n=number of affected teeth, N=number of teeth observable; i^1=1st incisor, i^2=2nd incisor, c=canine, m^1=1st molar, m^2=2nd molar).

Dental caries – permanent teeth

The prevalence of caries of the permanent dentition for all six samples is given in Tables 5.3.4 and 5.3.6 by number of individuals and number of teeth affected by caries, respectively. Among the British samples, Apple Down showed the highest prevalence with 38.95 percent of all individuals affected, while Castledyke South held an intermediate position with 27.87 percent and Norton revealed the lowest prevalence with only 15.07 percent affected by caries of their permanent teeth. Differences in caries prevalence between the British samples were found to be statistically significant (χ^2=8.7196, p=0.0032, d.f.=2). Variation was less obvious among the German sites and here no statistically significant difference was observed (χ^2=2.3333, p=0.3114, d.f.=2). Nusplingen had the highest caries frequency with more than half of all individuals affected (52.08 percent), followed by Pleidelsheim with 45.53 percent and Neresheim with 43.45 percent. The permanent dentition of subadult individuals was not affected in three samples – Castledyke South, Norton and Nusplingen – and at Neresheim and Pleidelsheim, rates were low. However, at Apple Down, 12.5 percent displayed carious lesions. With the exception of Norton, females had a higher caries prevalence than males in the British samples. Contrary to this observation, in two German samples – Nusplingen and Pleidelsheim – males were more often affected than females. At Neresheim, more females than males had dental caries. Nevertheless, these results have to be treated cautiously in the light of a large proportion of adults for whom sex could not be established.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
<16	2	16	12.5	<16	0	18	0.0	<16	0	14	0.0
F	25	46	54.35	F	22	56	39.29	F	3	28	10.71
M	9	31	29.03	M	11	43	25.58	M	5	19	26.32
N/D	1	2	50.0	N/D	1	5	20.0	N/D	3	12	25.0
Total	37	95	38.95	Total	34	122	27.87	Total	11	73	15.07
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
<16	1	29	3.45	<16	0	16	0.0	<16	1	27	3.7
F	35	62	56.45	F	30	52	57.69	F	25	47	53.19
M	23	45	51.11	M	34	54	62.96	M	28	41	68.29
N/D	4	9	44.44	N/D	11	22	50.0	N/D	2	8	25.0
Total	63	145	43.45	Total	75	144	52.08	Total	56	123	45.53

Table 5.3.4 Prevalence of dental caries by individuals affected in relation to individuals with at least one permanent tooth observable (n=number of individuals affected, N=number of individuals observable; <16=subadults below the age of 16 years, F=females, M=males, N/D=adults of undetermined sex).

Table 5.3.5 provides information on the overall caries prevalence for pooled samples by individuals affected. Applying chi-squared tests revealed that there were no statistically significant differences in caries frequency between the sexes within each country, although the difference between British female and male caries rates approached, but did not reach significance (British females and males: χ^2=3.2569, p=0.0711, d.f.=1; German females and males: χ^2=0.7130, p=0.3985, d.f.=1). Conversely, comparisons between the pooled samples were statistically significant for both sexes (British and German females: χ^2=11.3022, p=0.0008, d.f.=1; British and German males: χ^2=28.2288, p=0.0000, d.f.=1), with German females and males being more affected by the disease. Subsequently, German individuals had experienced significantly more caries than British individuals (χ^2=24.3664, p=0.0000, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
<16	2	48	4.17	<16	2	72	2.78
Females	50	130	38.46	Females	90	161	55.9
Males	25	93	26.88	Males	85	140	60.71
N/D	5	19	26.32	N/D	17	39	43.59
Total GB	82	290	28.28	Total D	194	412	47.09

Table 5.3.5 Prevalence of dental caries for pooled samples by individuals affected in relation to individuals with at least one permanent tooth observable (n=number of individuals affected, N=number of individuals with at least one tooth observable; <16=subadults below the age of 16 years, N/D=adults of undetermined sex).

However, focusing only on the number of affected individuals would necessitate that all skeletons had their dentitions of 32 teeth fully preserved to enable meaningful comparisons between and within the countries. This is clearly not the case for a number of reasons; from the 290 British individuals with permanent teeth 9,280 teeth should have been present. However, only 5,405 teeth were preserved (58.24 percent) and the percentage of observable teeth was even lower for the German samples; here, only 45.87 percent (6047 of 13,184 possible teeth) were present. Postmortem tooth loss accounts for a large proportion of these missing teeth, while some teeth were never formed or remained unerupted, and in subadult individuals, not all teeth could be scored because they had not fully erupted.

Concentrating on the number of teeth with dental caries in relation to the number of teeth observable (Table 5.3.6), again, the British samples had fewer caries compared to the German sites. Norton was still the British population with the lowest caries prevalence (1.43 percent) but, on the basis of observable teeth, at Castledyke South slightly more teeth (3.74 percent) had caries than at Apple Down (3.38 percent). Among the German samples, Nusplingen again had the highest caries prevalence (8.16 percent), while now Pleidelsheim had the lowest frequency (5.17 percent). At Neresheim, 7.37 percent of all observable teeth had one or more cavities. Subadults in both countries shared a low prevalence rate. The same pattern between female and male teeth was observed as for individuals in two samples, Norton and Neresheim, where females had fewer caries than males, while in the other four samples females had more carious lesions. However, a large number of teeth had to be grouped into the unsexable adult category, and the true proportions of female and male caries prevalence might have become distorted by this limitation.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
<16	2	261	0.77	<16	0	231	0	<16	0	197	0
F	51	1019	4.96	F	51	1041	4.90	F	5	464	1.08
M	18	810	2.22	M	24	836	2.87	M	7	344	2.03
N/D	1	33	3.03	N/D	6	57	10.53	N/D	4	112	3.57
Total	72	2123	3.38	Total	81	2165	3.74	Total	16	1117	1.43
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
<16	1	197	0.51	<16	0	70	0.0	<16	1	290	0.34
F	85	922	9.22	F	63	879	7.17	F	48	981	4.89
M	47	682	6.89	M	81	917	8.83	M	57	698	8.17
N/D	5	72	6.94	N/D	26	218	11.93	N/D	2	121	1.65
Total	138	1873	7.37	Total	170	2084	8.16	Total	108	2090	5.17

Table 5.3.6 Prevalence of dental caries by teeth affected in relation to teeth observable (n=number of teeth affected, N=number of teeth observable; <16=subadults below the age of 16 years, F=females, M=males, N/D=adults of undetermined sex).

The results for both pooled samples are summarized in Table 5.3.7 and Fig 5.3.1. For the pooled German samples caries prevalence was more than twice as high as for the pooled British sites (British samples: 3.13 percent, German samples: 6.88 percent). While British and German subadults had similar caries frequencies (British subadults: 0.29 percent, German subadults: 0.36 percent), British females had a lower caries prevalence than German females (British females: 4.24 percent, German females: 7.05 percent). Differences between British and German males were even more striking, with only 2.46 percent of British male teeth affected by caries, but 8.05 percent of German male teeth showing one or more carious cavities. German adult teeth to which no sex could be assigned had almost the same percentage of caries as German males, 8.03 percent, while 5.45 percent of British teeth from this category were affected.

	British samples				German samples		
	n	N	%		n	N	%
<16	2	689	0.29	<16	2	557	0.36
Females	107	2524	4.24	Females	196	2782	7.05
Males	49	1990	2.46	Males	185	2297	8.05
N/D	11	202	5.45	N/D	33	411	8.03
Total GB	169	5405	3.13	Total D	416	6047	6.88

Table 5.3.7 Prevalence of dental caries for pooled samples by teeth affected in relation to teeth observable (n=number of teeth affected, N=number of teeth observable; <16=subadults below the age of 16 years, N/D=adults of undetermined sex).

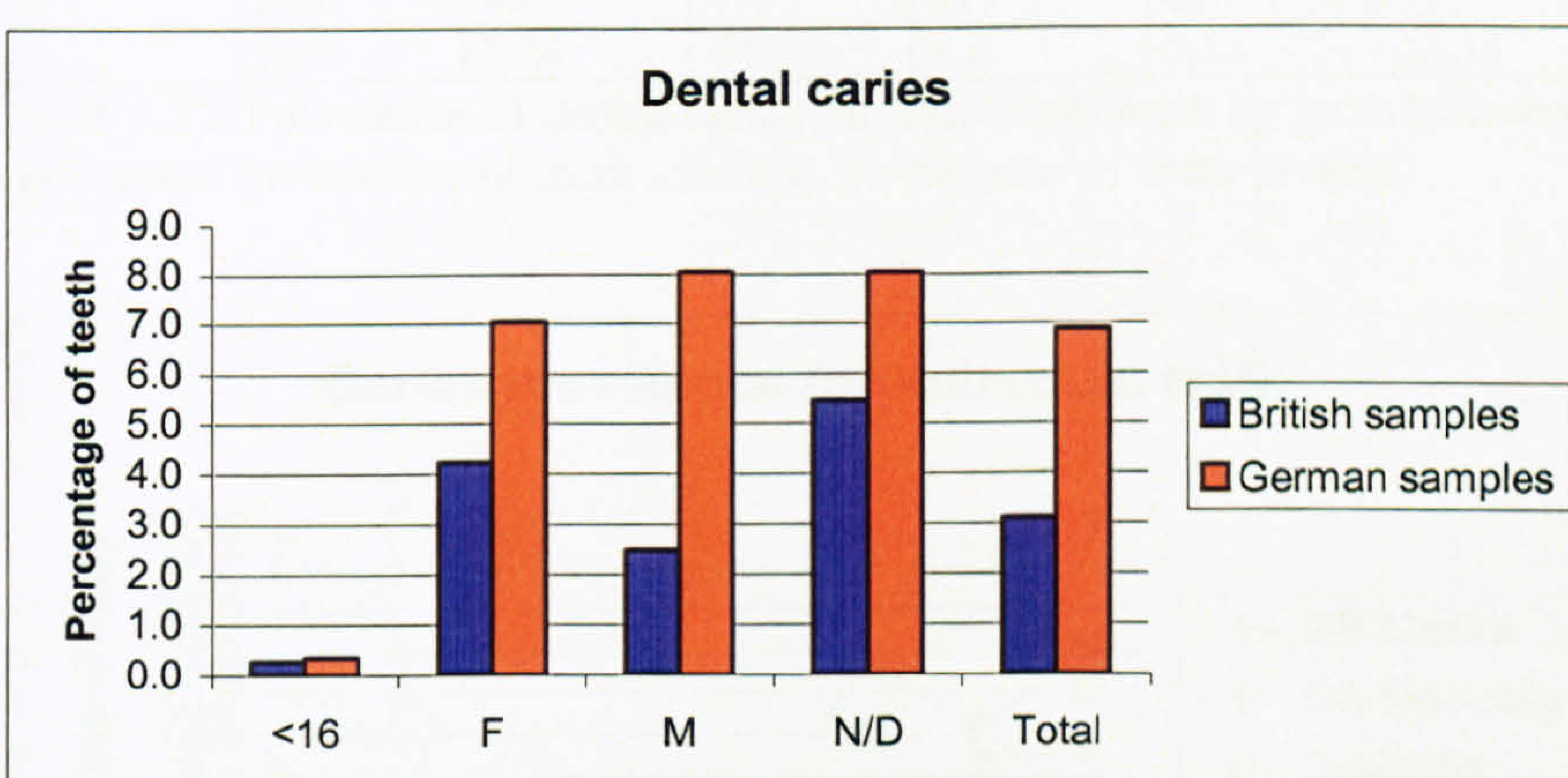


Fig. 5.3.1 Prevalence of dental caries for pooled samples by teeth affected in relation to teeth observable (<16=subadults below the age of 16 years, F=females, M=males, N/D=adult of undetermined sex).

Caries prevalence for individual teeth was tabulated in Table 5.3.8 and results are illustrated in Fig. 5.3.2. Maxillary and mandibular first and second incisors were rarely affected by caries; maxillary second incisors had no evidence of caries in the British samples. In both samples, maxillary canines had slightly more cavities than mandibular canines, but German canines were more than twice as often affected as British canines. Second premolars had a higher caries prevalence when compared to first premolars and, again, teeth from the German samples had a higher prevalence. This pattern was also observed for molars. However, a steady rise in prevalence from the first to third molars, both in the maxilla and mandible, was seen in the British samples. Among the German samples, the second maxillary molar had the highest caries rate, while in the mandible the second was the least affected molar and the third molar was most often involved.

Maxilla	British samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	3	0	7	7	8	19	29	19
N	318	306	352	340	339	373	328	205
%	0.94	0.0	1.99	2.06	2.36	5.09	8.54	9.27
Mandible	British samples							
n	2	4	6	6	10	15	20	15
N	331	384	390	394	382	371	371	232
%	0.6	1.04	1.54	1.52	2.62	4.04	5.39	6.47
Maxilla	German samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	1	4	16	23	29	41	61	25
N	297	331	387	393	399	420	333	208
%	0.34	1.21	4.13	5.85	7.27	9.76	18.32	12.02
Mandible	German samples							
n	1	10	17	21	31	52	41	42
N	349	439	479	477	436	397	403	299
%	0.29	2.28	3.55	4.4	7.11	13.35	10.17	14.05

Table 5.3.8 Prevalence of dental caries for individual teeth by teeth affected in relation to teeth observable (n=number of teeth affected, N=number of teeth present).

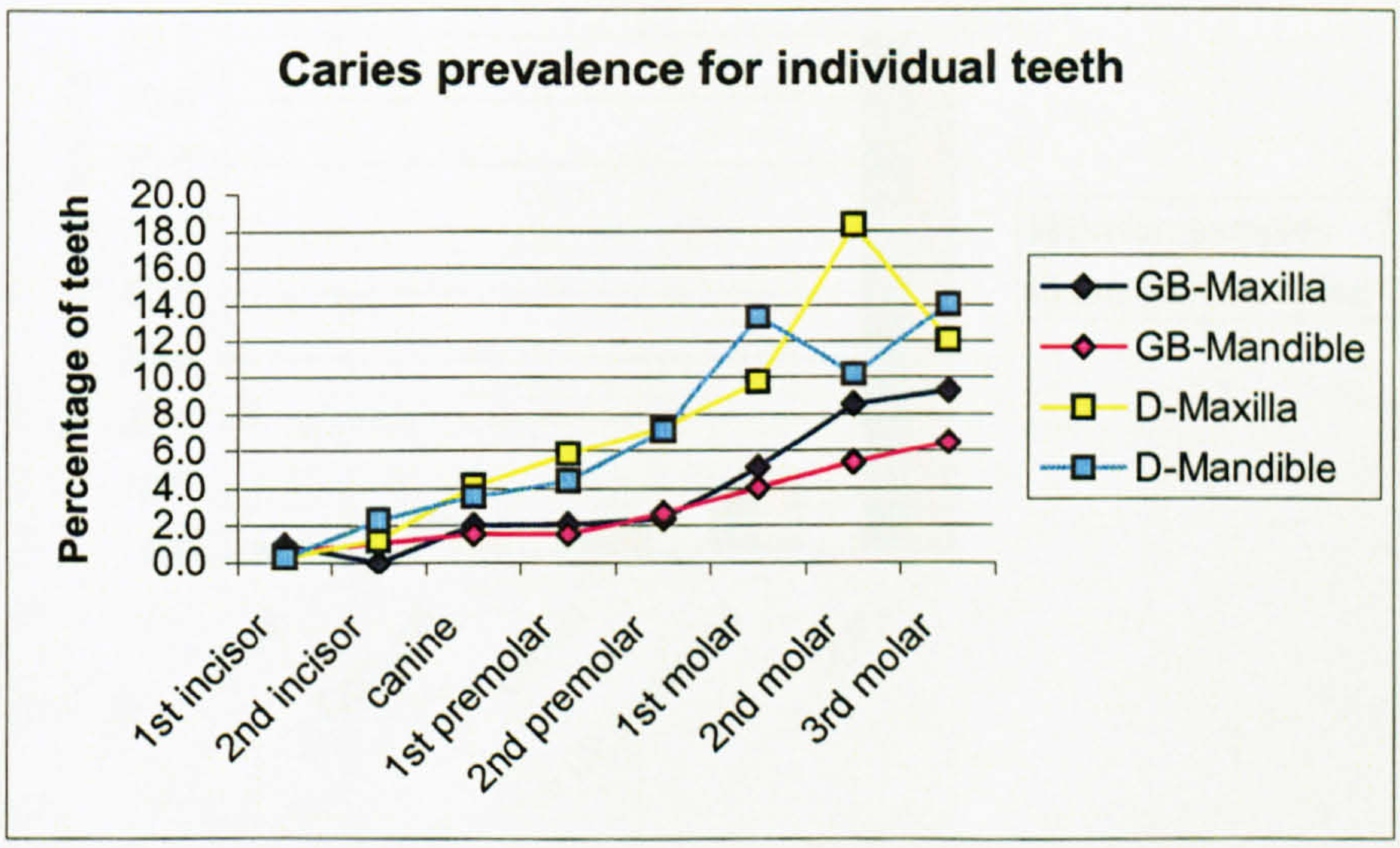


Fig. 5.3.2 Prevalence of dental caries for individual teeth affected in relation to teeth observable – pooled samples (GB=pooled British samples, D=pooled German samples).

Caries location on each tooth is seen in Fig. 5.3.3 and the distribution of carious lesions between the two pooled samples is close to identical. A total of 176 and 439 cavities were assessed for the British and German samples, respectively. The discrepancy in numbers of carious teeth and caries lesions analysed for their location derives from the fact that several teeth had more than one lesion. In both pooled samples, root surface caries occurred rarely (British samples: 1.7 percent, German samples: 1.82 percent). Caries located on the occlusal surface was present on 5.11 percent of British teeth and 4.78 percent of German teeth. Smooth surfaces of the tooth crown had a caries prevalence of 3.41 percent of the British and 3.87 percent of the German samples. German teeth had a slightly higher frequency of gross caries where more than one-half of the crown was destroyed; 9.66 percent of British teeth and 12.07 percent of German teeth were seriously affected by dental caries. The highest number of cavities in both countries was located on the cemento-enamel junction (CEJ). British teeth had slightly more lesions (80.11 percent) compared to 77.45 percent for the German samples, but the distribution of lesions on the CEJ was similar in both samples. Lesions were most often located on the distal aspect of teeth (ca. 50.0 percent), followed by the mesial side (ca. 42.0 percent); lesions occurred less frequently on the labial/buccal (ca. 7.0 percent) and palatinal/lingual surfaces (ca. 1.0 percent).

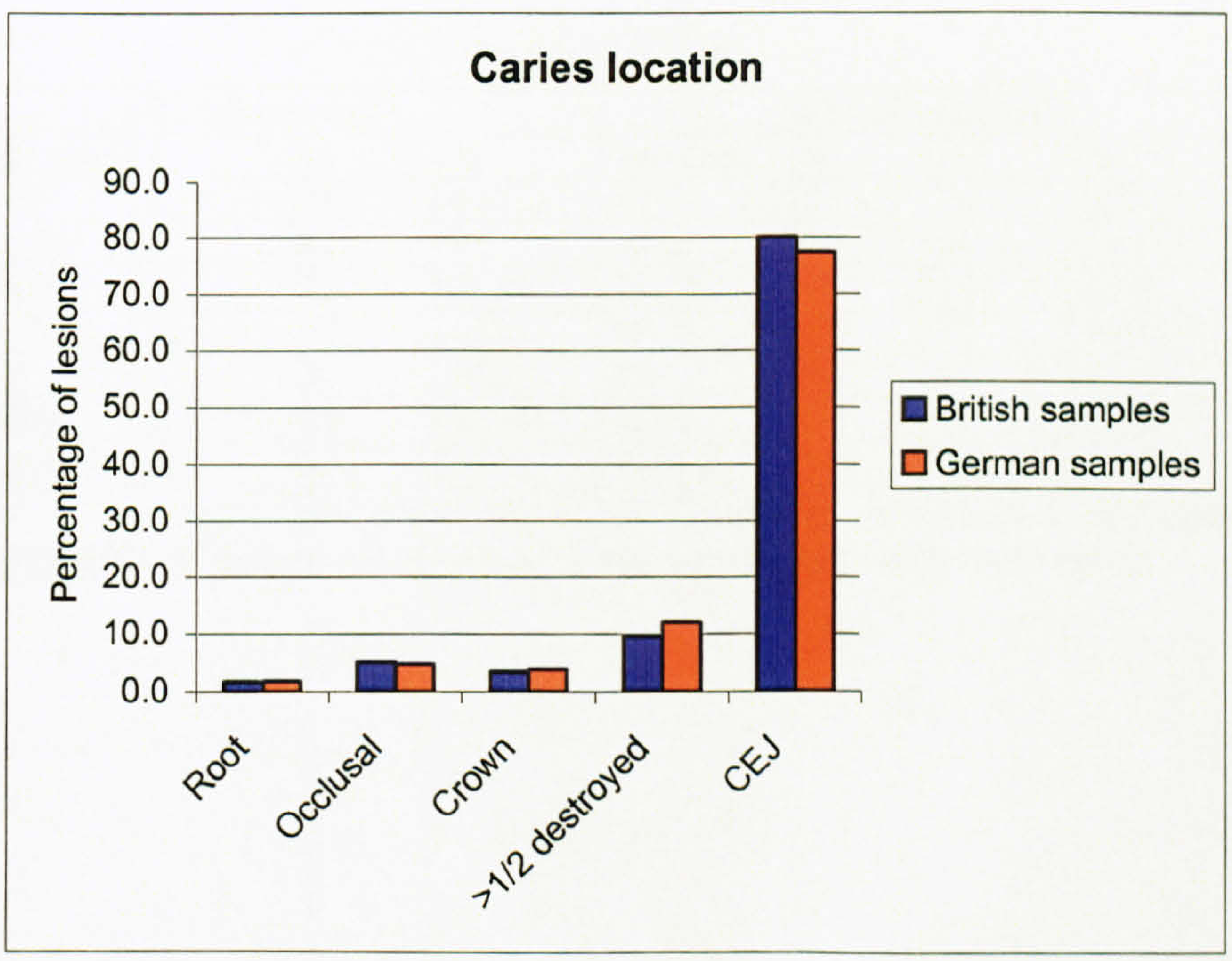


Fig. 5.3.3 Carious cavity location by number of lesions for pooled samples (Root=root surface caries, Occlusal=occlusal surface caries, Crown= caries on smooth surfaces of crown, >1/2 destroyed=more than one-half of crown destroyed, CEJ=caries on cemento-enamel junction).

Since dental caries is a disease which progresses with advancing age, differences between different age categories within and across the pooled samples were examined and the results are summarized in Table 5.3.9 as well as in Fig. 5.3.4 by individuals affected. In the British samples, caries prevalence rose steadily from the youngest to the oldest age category. Caries frequency more than doubled in the young adult age category (9.3 percent) and approximately tripled in the next oldest age class (29.17 percent). The increase in caries prevalence continued in the middle-age category, although not as sharply as before (45.21 percent). Half of all British individuals over the age of 45 years had at least one carious lesion. Caries prevalence in the German samples showed already a marked increase in the young adult age class (36.11 percent). A peak was reached in the young-middle adult category, where more than 60.0 percent (61.90 percent) were affected. Caries prevalence slightly dropped to 59.78 percent for middle-aged adults and more than half of all old adults had experienced caries (55.88 percent). However, almost one-third (32.14 percent) of British individuals and more than half (51.92 percent) of German skeletons could not be assigned to a more specific age class other than 'adult' and this might have distorted caries frequencies in individual age bands. Furthermore, it is not known at what age a lesion established itself and in the case of a person, having several cavities it is likely that not all lesions developed at the same time.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
<16	2	48	4.17	<16	2	72	2.78
16-25	4	43	9.3	16-25	13	36	36.11
26-35	21	72	29.17	26-35	78	126	61.9
36-45	33	73	45.21	36-45	55	92	59.78
45+	13	26	50.0	45+	19	34	55.88
Adult	9	28	32.14	Adult	27	52	51.92
Total GB	82	290	28.28	Total D	194	412	47.09

Table 5.3.9 Age-related prevalence of dental caries by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

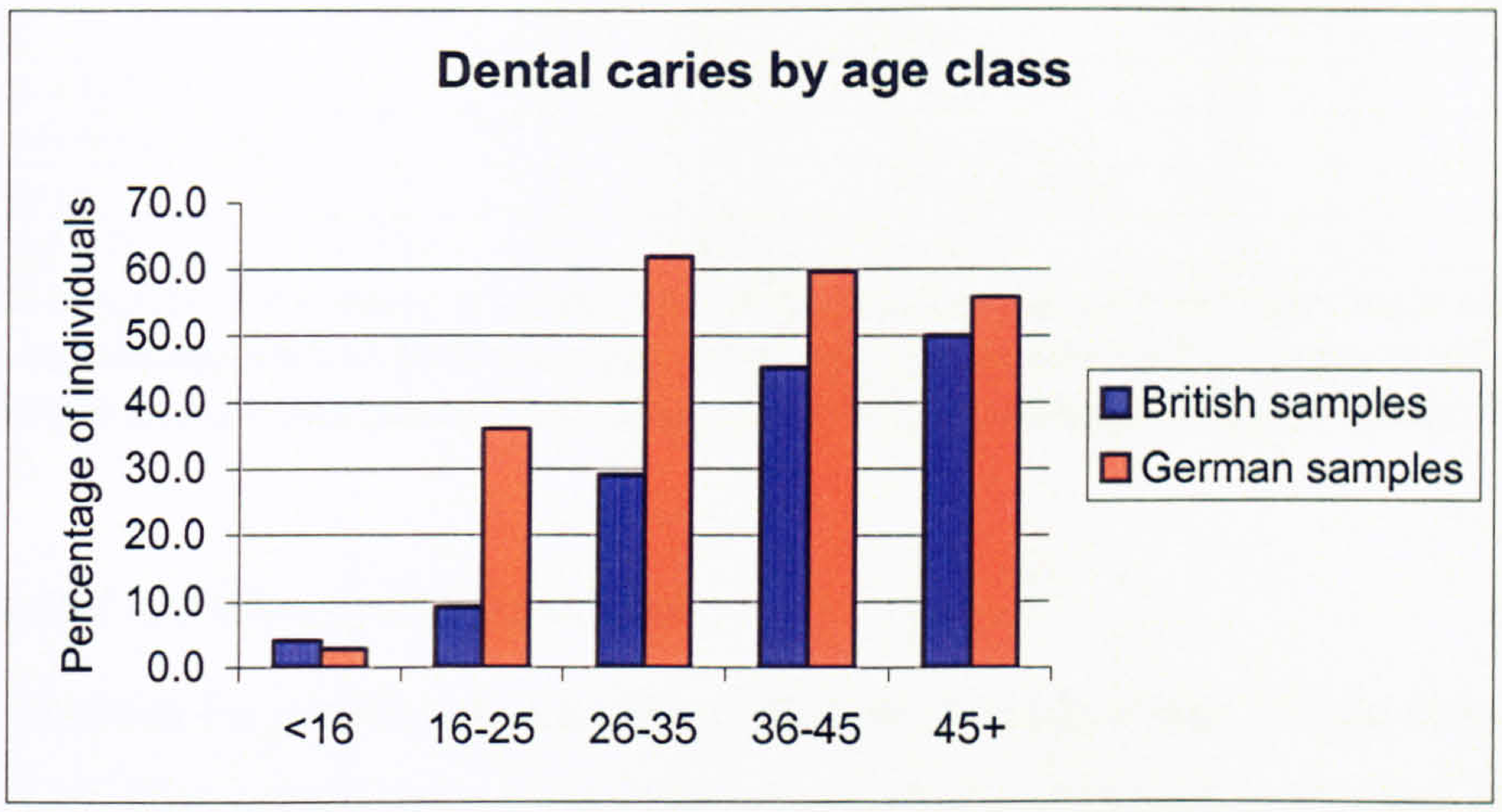


Fig. 5.3.4 Age-related prevalence of dental caries by individuals affected in relation to individuals observable by age class.

5.3.2 Dental calculus

Dental calculus – deciduous teeth

Due to the previously discussed problems with the analysis of dental calculus (see 4.2.6 Diagnosis of pathological conditions, p. 93), results were only obtained for affected individuals rather than individual teeth. Subadults within each of the six study samples yielded very different rates for dental calculus of their primary dentition and the results can be seen in Table 5.3.10. Prevalence was highest at Apple Down, where 35.0 percent of non-adult individuals were affected. Lower rates were found at Castledyke South, with one-quarter having evidence of calculus, and at Norton, where only 8.33 percent were affected. At Neresheim, slightly more than one-quarter of all individuals with deciduous teeth present had calculus deposits (26.09 percent) and at Nusplingen, 18.18 percent had experienced dental calculus. However, none of the 19 non-adults from Pleidelsheim was found to display calculus deposits. The overall prevalence for pooled British sites amounted to one-quarter of individuals being affected, while prevalence for the German samples was lower, with 15.09 percent. However, calculus prevalence for the deciduous dentition between the two countries was statistically insignificant (χ^2=1.4977, p=0.2210, d.f.=1).

Site	n	N	%	Site	n	N	%
Apple Down	7	20	35.0	Neresheim	6	23	26.09
Castledyke South	3	12	25.0	Nusplingen	2	11	18.18
Norton	1	12	8.33	Pleidelsheim	0	19	0.0
Total GB	11	44	25.0	Total D	8	53	15.09

Table 5.3.10 Prevalence of dental calculus (deciduous teeth) by individuals affected in relation to individuals with at least one tooth observable (n=number of individuals affected, N=number of individuals observable; Total GB=pooled British samples, Total D=pooled German samples).

Dental calculus – permanent teeth

Results for permanent calculus prevalence by individuals can be seen in Table 5.3.11. Highest prevalence rates for all samples were found at Castledyke South (83.61 percent), closely followed by Nusplingen (83.33 percent). Apple Down and Neresheim had similar rates with 77.89 percent and 70.34 percent, respectively. Norton and Pleidelsheim had comparatively low frequencies, with slightly more than half of all individuals affected, or 58.11 percent at Norton and 53.66 percent at Pleidelsheim.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
<16	10	16	62.5	<16	13	18	72.22	<16	7	14	50.0
F	36	46	78.26	F	50	56	89.29	F	18	28	64.29
M	27	31	87.1	M	36	43	83.72	M	12	19	63.16
N/D	1	2	50.0	N/D	3	5	60.0	N/D	6	12	50.0
Total	74	95	77.89	Total	102	122	83.61	Total	43	73	58.11
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
<16	7	29	24.14	<16	1	16	6.25	<16	6	27	22.22
F	55	62	88.71	F	49	52	94.23	F	33	47	70.21
M	36	45	80.0	M	50	54	92.59	M	25	41	60.98
N/D	4	9	44.44	N/D	20	22	90.91	N/D	2	8	25.0
Total	102	145	70.34	Total	120	144	83.33	Total	66	123	53.66

Table 5.3.11 Prevalence of dental calculus (permanent teeth) by individuals affected in relation to individuals with at least one tooth observable (n=number of individuals affected, N=number of individuals observable; <16=subadults below the age of 16 years, F=females, M=males, N/D=adults of undetermined sex).

From this, and the following table (Table 5.3.12) which details data for pooled samples, one striking difference between the British and German samples becomes obvious: while British subadults had similarly high rates compared to adults, their German counterparts were much less affected by dental calculus. This difference in dental calculus deposits among non-adults was highly significant (χ^2=23.0789, p=0.0000, d.f.=1). Frequencies between British females and males were close to identical, while among the German samples females were slightly more often affected but differences were statistically insignificant between and within each pooled sample

(British and German females: χ^2=2.6741, p=0.1020, d.f.=1, British and German males: χ^2=0.0641, p=0.8001, d.f.=1; British females and males: χ^2=0.0142, p=0.9050, d.f.=1, German females and males: χ^2=1.7409, p=0.1870, d.f.=1). Ultimately, although German individuals had less dental calculus of their permanent dentition, this difference was statistically not significant (χ^2=1.3111, p=0.2522, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
<16	30	48	62.5	<16	14	72	19.44
Females	104	130	80.0	Females	137	161	85.09
Males	75	93	80.65	Males	111	140	79.29
N/D	10	19	52.63	N/D	26	39	66.67
Total GB	219	290	75.52	Total D	288	412	69.9

Table 5.3.12 Prevalence of dental calculus (permanent teeth) for pooled samples by individuals affected in relation to individuals observable (n=number of individuals affected, N=number of individuals with at least one tooth observable; <16=subadults below the age of 16 years, N/D=adults of undetermined sex).

5.3.3 Periapical lesions and pulp exposure

Periapical abscesses were only found in adult individuals and for this reason non-adults were not considered in the analysis of this particular dental disease. Prevalence rates for each site by individuals affected are presented in Table 5.3.13.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	11	43	25.58	F	7	50	14.0	F	1	25	4.0
M	7	31	22.58	M	4	36	11.11	M	0	16	0.0
N/D	0	2	0.0	N/D	0	3	0.0	N/D	0	4	0.0
Total	18	76	23.68	Total	11	89	12.36	Total	1	45	2.22
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		N	N	%		n	N	%
F	14	61	22.95	F	11	52	21.15	F	10	46	21.74
M	11	47	23.4	M	12	59	20.34	M	9	37	24.32
N/D	0	4	0.0	N/D	7	23	30.43	N/D	0	4	0.0
Total	25	112	22.32	Total	30	134	22.39	Total	19	87	21.84

Table 5.3.13 Prevalence of periapical lesions by individuals affected in relation to individuals with at least one tooth position observable (n=number of individuals with periapical lesions, N=number of individuals observable; F=females, M=males, N/D=adults of undetermined sex).

Among the British samples, Apple Down had the highest prevalence with 23.68 percent. At Castledyke South, a much lower prevalence was found; here, only 12.36 percent were affected. However, Norton yielded by far the lowest frequency. Only one individual of 45 (2.22 percent) had periapical lesions. The three German samples had more consistently high rates, all lying slightly below 25.0 percent. In detail, Neresheim yielded a frequency of 22.32 percent, at Nusplingen, 22.39 percent were affected and at Pleidelsheim, 21.84 percent suffered periapical lesions.

Data for pooled samples from both countries are tabulated in Table 5.3.14 and a graphic representation of these results can be found in Fig. 5.3.5. British females had slightly elevated rates (16.1 percent) when compared to British males (13.25 percent). However, German females and males had very similar frequencies with 22.01 percent and 22.38 percent affected, respectively. While no statistically significant difference was present between British and German females (χ^2=1.5079, p=0.2195, d.f.=1) or British and German males (χ^2=3.2327, p=0.0722, d.f.=1), overall frequencies proved to be high enough to make this difference between the two countries statistically significant (χ^2=5.2125, p=0.0224, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
Females	19	118	16.1	Females	35	159	22.01
Males	11	83	13.25	Males	32	143	22.38
N/D	0	9	0.0	N/D	7	31	22.58
Total GB	30	210	14.29	Total D	74	333	22.22

Table 5.3.14 Prevalence of periapical lesions for pooled samples by individuals affected in relation to individuals observable (n=number of individuals with periapical lesions, N=number of individuals with at least one tooth position observable, N/D=adults of undetermined sex).

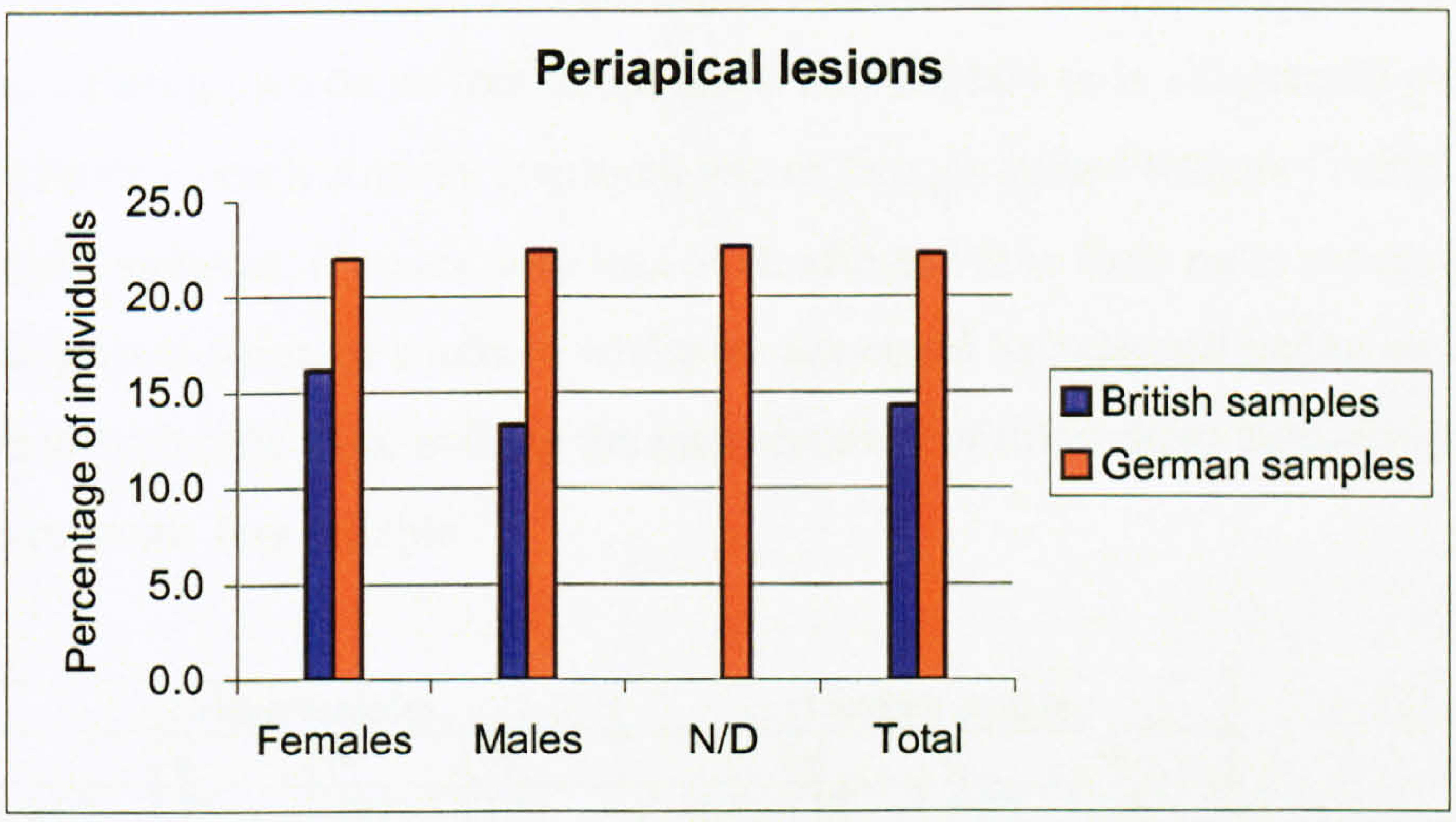


Fig. 5.3.5 Prevalence of periapical lesions by sex for pooled samples by number of individuals affected in relation to individuals observable (N/D=adults of undetermined sex).

The same data was tabulated for tooth positions observable; Table 5.3.15 provides information on each of the six samples, and in Table 5.3.16 pooled results are presented. Among the British sites, Apple Down again had the highest prevalence with 1.39 percent of all observable tooth positions showing periapical lesions. However, the rate for Castledyke South was not much lower; 1.33 percent of tooth positions displayed periapical lesions. Corresponding to the low rate encountered for affected individuals, Norton yielded a very low prevalence with 0.22 percent. Little variation in periapical lesion prevalence was observed for the German sites. Neresheim had the highest frequency with 1.57 percent, followed by Pleidelsheim with 1.39 percent and Nusplingen had the lowest prevalence with 1.17 percent of all observable tooth positions affected.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	14	1214	1.15	F	13	1105	1.18	F	2	552	0.36
M	16	907	1.76	M	12	761	1.58	M	0	283	0.0
N/D	0	31	0.0	N/D	0	13	0.0	N/D	0	62	0.0
Total	30	2152	1.39	Total	25	1879	1.33	Total	2	897	0.22
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
F	19	1464	1.3	F	15	1353	1.11	F	14	1196	1.17
M	22	1089	2.02	M	16	1517	1.05	M	16	896	1.79
N/D	0	51	0.0	N/D	7	369	1.9	N/D	0	68	0.0
Total	41	2604	1.57	Total	38	3239	1.17	Total	30	2160	1.39

Table 5.3.15 Prevalence of periapical lesions by tooth positions affected in relation to tooth positions observable (n=number of periapical lesions, N=number of tooth positions observable, F=females, M=males, N/D=adults of undetermined sex).

Differences in overall prevalence for pooled samples by tooth positions affected were less striking than on an individual basis. Just slightly over 1.0 percent of all tooth positions in each country displayed one or two periapical lesions (Table 5.3.16). In both pooled samples, females were less often affected than their male counterparts. However, a high proportion of adults to whom no sex could be assigned had to be included in the German sample data, making the interpretation of differences between female and male frequencies less reliable.

	British samples				German samples		
	n	N	%		n	N	%
Females	29	2871	1.01	Females	48	4013	1.2
Males	28	1951	1.44	Males	54	3502	1.54
N/D	0	106	0.0	N/D	7	488	1.43
Total GB	57	4928	1.16	Total D	109	8003	1.36

Table 5.3.16 Prevalence of periapical lesions for pooled samples by tooth positions affected in relation to tooth positions observable (n=number of periapical lesions, N=number of tooth positions observable, N/D=adults of undetermined sex).

Age-related prevalence of periapical lesions (individual count) is tabulated in Table 5.3.17 and the same data is displayed in Fig. 5.3.6. In both countries, a steady increase in prevalence with advancing age was noticed. However, this increase was much more severe for the German samples, where in the young-middle age category more than one-fifth (21.6 percent) of individuals were affected, while the corresponding age category in the British samples only had 11.11 percent of individuals involved. Differences between the countries were less marked in the two oldest age categories. However, in all cases German individuals had higher prevalence rates.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	1	40	2.5	16-25	3	31	9.68
26-35	7	63	11.11	26-35	27	125	21.6
36-45	13	67	19.4	36-45	24	94	25.53
45+	7	23	30.43	45+	13	39	33.33
Adult	2	17	11.76	Adult	7	44	15.91
Total GB	30	210	14.29	Total D	74	333	22.22

Table 5.3.17 Age-related prevalence of periapical lesions by individuals affected in relation to individuals observable per age class (n=number of individuals affected, N=number of individuals observable, Total GB=pooled British samples, Total D=pooled German samples).

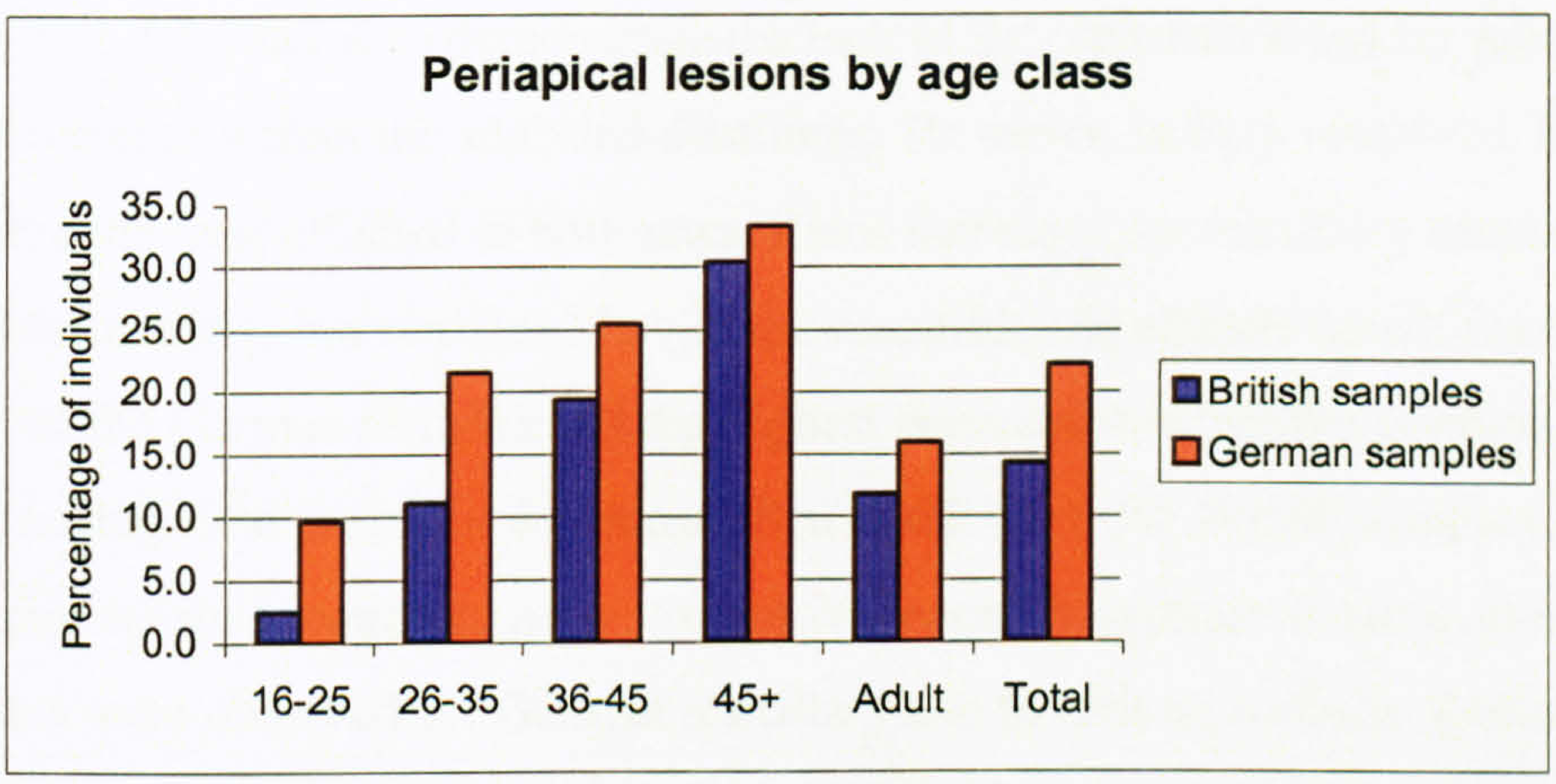


Fig. 5.3.6 Age-related prevalence of periapical lesions by individuals affected in relation to individuals observable per age class.

Table 5.3.18 and Fig. 5.3.7 give detailed information on which tooth position most frequently displayed periapical lesions. In the pooled British samples, almost 3.0 percent (2.96 percent) of all observable tooth positions of the maxilla were located near the first premolar, followed by the first molar (2.1 percent). British mandibles had the highest prevalence at the level of the first molar (3.19 percent) and the second molar (1.75 percent). Within German maxillae, the canine was the site with the highest prevalence rate (3.85 percent), followed by the first and second molars (3.12 percent and 3.0 percent). German mandibles showed a high prevalence at the position of the third molar (2.04 percent).

Maxilla	British samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	2	5	4	9	2	6	5	1
N	291	293	303	304	297	286	261	212
%	0.69	1.71	1.32	2.96	0.67	2.1	1.75	0.47
Mandible	British samples							
n	1	0	2	1	1	11	6	1
N	332	342	339	336	338	345	343	306
%	0.3	0.0	0.59	0.3	0.3	3.19	1.75	0.33
Maxilla	German samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	2	8	19	10	9	14	12	3
N	496	494	494	491	476	449	400	309
%	0.4	1.62	3.85	2.04	1.89	3.12	3.0	0.97
Mandible	German samples							
n	0	1	3	3	2	8	5	10
N	550	558	562	564	568	556	546	490
%	0.0	0.18	0.53	0.53	0.35	1.44	0.92	2.04

Table 5.3.18 Prevalence of periapical lesions by tooth positions affected in relation to tooth positions observable (n=number of tooth positions affected, N=number of tooth positions observable).

Fig. 5.3.7 helps to demonstrate the lack of any apparent trend for periapical lesion prevalence within the analysed dentitions. However, in both countries, first incisors were the least affected in both jaws. Rates increased for maxillary second incisors in both countries but remained low in the mandible. As already noted, maxillary canines from the German samples had the highest prevalence, while the position of the maxillary first premolar was most often involved in the British samples. Rates dropped again for the second premolar, except for second premolars in German maxillae. Similar rates were observed for German maxillary and British mandibular first molars and prevalence decreased again at the second molar position. A further decrease was observed for the third molar, with the exception of German mandibles. Considering all British tooth positions, rates for maxillae were almost twice as high as for mandibles (maxillae: 1.51 percent, mandibles: 0.86 percent). This difference between maxillary and mandibular locations of periapical lesions was almost three times as high in German maxillae compared to German mandibles (maxillae: 2.13 percent, mandibles: 0.73 percent).

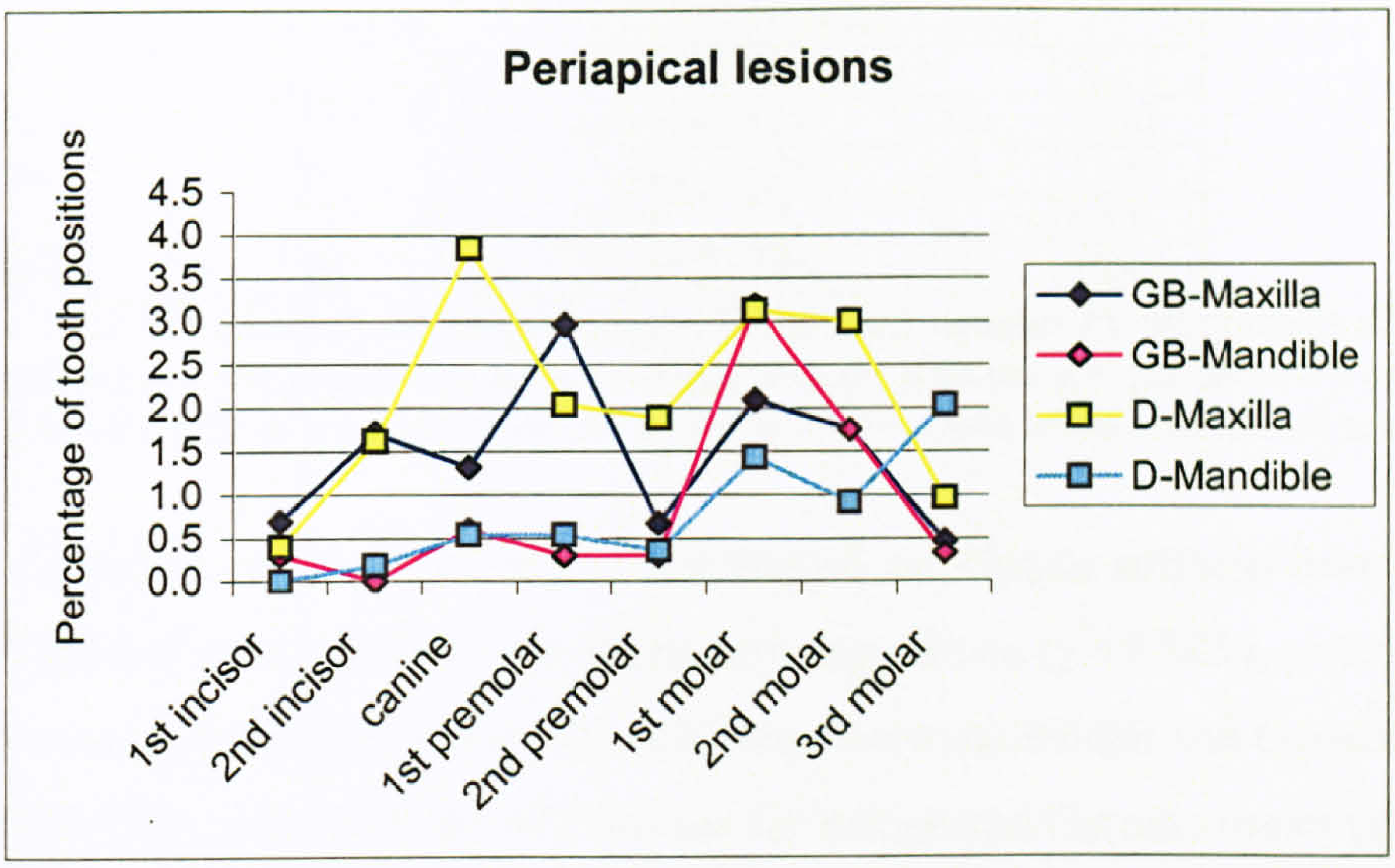


Fig. 5.3.7 Prevalence of periapical lesions by tooth positions affected in relation to tooth positions observable.

Results for individuals displaying pulp exposure in the six study samples are tabulated in Table 5.3.19; pooled sample results are presented in Table 5.3.20. With the exception of Apple Down, individuals at Castledyke South (4.81 percent) and Norton (3.39 percent) had relatively little evidence of pulp exposure. However, 16.46 percent of individuals at Apple Down displayed this condition. Among the German samples, Pleidelsheim had the highest prevalence with 23.96 percent of all individuals affected. At Neresheim, 15.52 percent had experienced pulp exposure of one or more teeth and slightly more than one-tenth (11.72 percent) of all individuals from Nusplingen had pulp exposure.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	6	46	13.04	F	1	56	1.79	F	0	28	0.0
M	7	31	22.58	M	4	43	9.3	M	2	19	10.53
N/D	0	2	0.0	N/D	0	5	0.0	N/D	0	12	0.0
Total	13	79	16.46	Total	5	104	4.81	Total	2	59	3.39
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		N	N	%		n	N	%
F	14	62	22.58	F	7	52	13.46	F	8	47	17.02
M	4	45	8.89	M	6	54	11.11	M	15	41	36.59
N/D	0	9	0.0	N/D	2	22	9.09	N/D	0	8	0.0
Total	18	116	15.52	Total	15	128	11.72	Total	23	96	23.96

Table 5.3.19 Prevalence of pulp exposure by individuals affected in relation to individuals with at least one tooth observable (n=number of individuals with pulp exposure, N=number of individuals observable, F=females, M=males, N/D=adults of undetermined sex).

	British samples				German samples		
	n	N	%		n	N	%
Females	7	130	5.38	Females	29	161	18.01
Males	13	93	13.98	Males	25	140	17.86
N/D	0	19	0.0	N/D	2	39	5.13
Total GB	20	242	8.26	Total D	56	340	16.47

Table 5.3.20 Prevalence of pulp exposure for pooled samples by individuals affected in relation to individuals observable (n=number of individuals with pulp exposure, N=number of individuals with at least one tooth observable, N/D=adults of undetermined sex).

Almost twice as many German than British individuals suffered from pulp exposure and the difference proved to be statistically significant (χ^2=8.3854, p=0.0038, d.f.=1). This was equally observed for the difference between British and German females (χ^2=10.5795, p=0.0011, d.f.=1), but not for British and German males (χ^2=0.6159, p=0.4326, d.f.=1). Likewise, differences in prevalence rates between German females and males were not large enough to produce statistical significance (χ^2=0.0012, p=0.9721, d.f.=1). However, British females had significantly less pulp exposure than their male counterparts (χ^2=4.5924, p=0.0321, d.f.=1).

Data for pulp exposure by teeth affected for each of the six sites is presented in Table 5.3.21. Among the British samples, Apple Down again yielded the highest prevalence rate with 1.13 percent of all teeth affected, followed by Castledyke South, where 0.41 percent of teeth displayed pulp exposure. The lowest frequency was found at Norton; here, 0.33 percent of teeth were affected. The highest prevalence rate among all six samples was found at Pleidelsheim, where 2.83 percent had pulp exposure. This is more than twice the prevalence calculated for teeth from Neresheim, where 1.31 percent of teeth were affected. An even lower frequency was found at Nusplingen, with 0.89 percent of teeth involved.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	9	1019	0.88	F	1	1041	0.1	F	0	464	0.0
M	12	810	1.48	M	7	836	0.84	M	3	344	0.87
N/D	0	33	0.0	N/D	0	57	0.0	N/D	0	112	0.0
Total	21	1862	1.13	Total	8	1934	0.41	Total	3	920	0.33
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
F	18	922	1.95	F	9	879	1.02	F	19	981	1.94
M	4	682	0.59	M	7	917	0.76	M	32	698	4.58
N/D	0	72	0.0	N/D	2	218	0.92	N/D	0	121	0.0
Total	22	1676	1.31	Total	18	2014	0.89	Total	51	1800	2.83

Table 5.3.21 Prevalence of pulp exposure by teeth affected in relation to teeth observable (n=number of teeth with pulp exposure, N=number of teeth observable, F=females, M=males, N/D=adults of undetermined sex).

Table 5.3.22 displays pulp exposure frequencies for pooled samples from both countries. Overall prevalence for British teeth was low; 0.68 percent were affected by pulp exposure, while German teeth yielded a prevalence rate of 1.66 percent. Differences between British and German males (1.11 percent and 1.87 percent, respectively) were less marked than for British and German females (0.4 percent and 1.65 percent, respectively). The same was true for German females and males. However, British males had more than twice as many teeth displaying pulp exposure than British females.

	British samples				German samples		
	n	N	%		n	N	%
Females	10	2524	0.4	Females	46	2782	1.65
Males	22	1990	1.11	Males	43	2297	1.87
N/D	0	202	0.0	N/D	2	411	0.49
Total GB	32	4716	0.68	Total D	91	5490	1.66

Table 5.3.22 Prevalence of pulp exposure for pooled samples by teeth affected in relation to teeth observable (n=number of teeth with pulp exposure, N=number of teeth observable, N/D=adults of undetermined sex).

In Table 5.3.23, prevalence for individual teeth is presented for British and German pooled samples. The first maxillary and mandibular molars were most often affected in the British samples, while the second mandibular molar and the first maxillary premolar yielded the highest prevalence among the German samples.

Maxilla	British samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	0	0	2	3	2	9	0	1
N	318	306	352	340	339	373	328	205
%	0.0	0.0	0.57	0.88	0.59	2.41	0.0	0.49
Mandible	British samples							
n	0	1	0	0	0	9	5	0
N	331	384	390	394	382	371	371	232
%	0.0	0.26	0.0	0.0	0.0	2.43	1.35	0.0
Maxilla	German samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	3	6	12	9	7	5	7	0
N	297	331	387	393	399	420	333	208
%	1.01	1.81	3.1	2.29	1.75	1.19	2.1	0.0
Mandible	German samples							
n	2	1	2	2	7	15	8	5
N	349	439	479	477	436	397	403	299
%	0.57	0.23	0.42	0.42	1.61	3.78	1.99	1.67

Table 5.3.23 Prevalence of pulp exposure by teeth affected in relation to teeth observable (n=number of teeth affected, N=number of teeth observable).

Prevalence rates for periapical lesions and pulp exposure are plotted against each other and the results can be found in Figs. 5.3.8 and 5.3.9. In both pooled samples, tooth positions which exhibit periapical lesions were also likely to display pulp exposure.

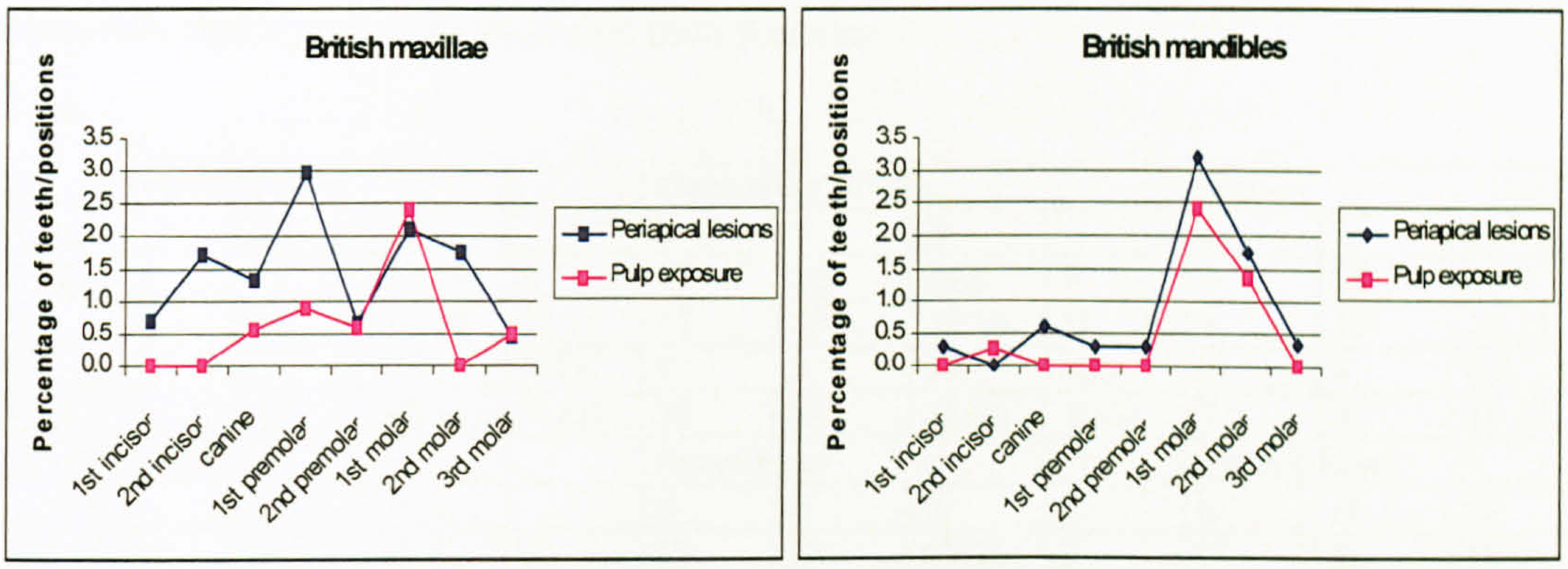


Fig. 5.3.8 Prevalence of periapical lesions and pulp exposure for pooled British samples by teeth/positions affected.

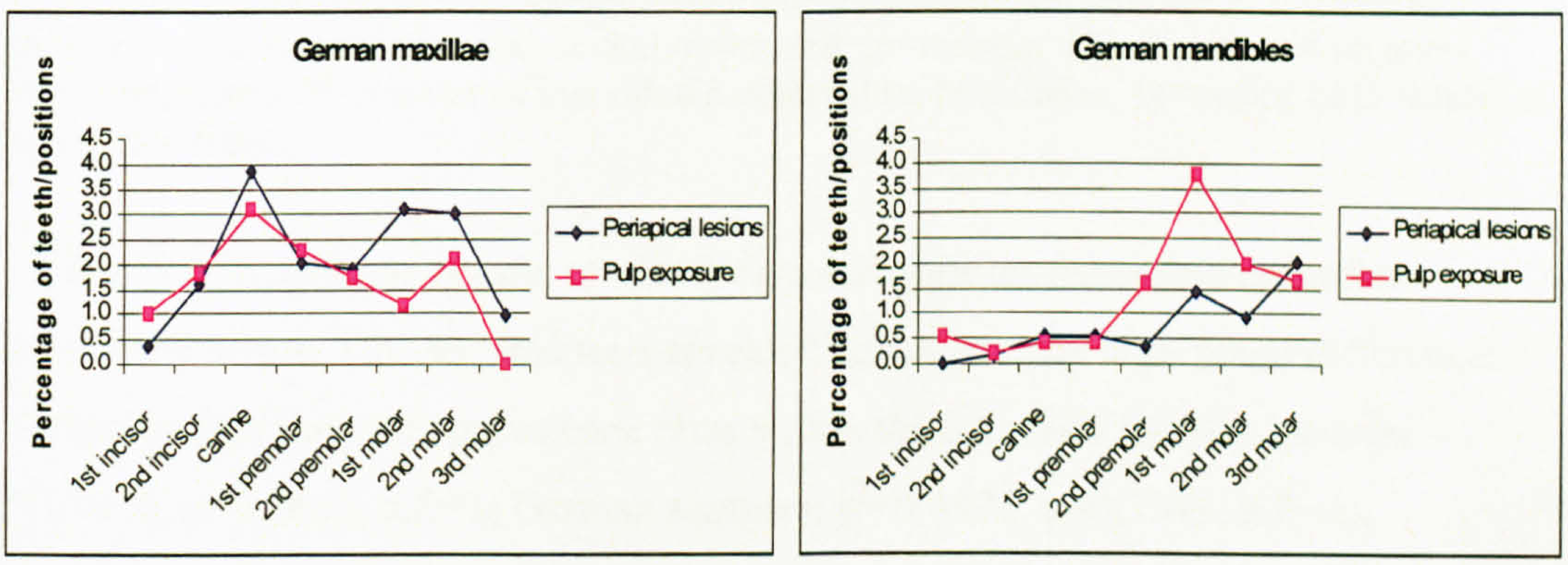


Fig. 5.3.9 Prevalence of periapical lesions and pulp exposure for pooled German samples by teeth/positions affected.

5.3.4 Ante-mortem tooth loss (AMTL)

Table 5.3.24 demonstrates differences in ante-mortem tooth loss (AMTL) prevalence for the six study samples. AMTL was restricted to adult individuals, with one exception; one subadult from Neresheim (NE41), aged 12-14 years, had both mandibular second premolars lost during life. However, as this was the only subadult affected by ante-mortem tooth loss, no prevalence rate was calculated and this individual was not included in further analyses. Among the British sites, Apple Down had the highest frequency with 42.11 percent of all individuals affected. At Castledyke South, less than one-third (31.46 percent) of individuals displayed tooth loss during life and even lower figures were found at Norton; here, 15.56 percent of all individuals had experienced AMTL. In contrast, prevalence for German sites was considerably higher, and more than half of the adult population had one or more teeth lost ante-mortem. Rates were highest at Neresheim, where 58.0 percent of all individuals were involved. However, at Nusplingen and Pleidelsheim, AMTL prevalence was not much lower with 56.72 percent and 55.17 percent, respectively. Only at two sites, Norton and Pleidelsheim, had male individuals higher frequencies than females.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	22	43	51.16	F	17	50	34.0	F	4	25	16.0
M	10	31	32.26	M	11	36	30.56	M	3	16	18.75
N/D	0	2	0.0	N/D	0	3	0.0	N/D	0	4	0.0
Total	32	76	42.11	Total	28	89	31.46	Total	7	45	15.56
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
F	39	61	63.93	F	33	52	63.46	F	23	46	50.0
M	26	47	55.32	M	33	59	55.93	M	23	37	62.16
N/D	0	4	0.0	N/D	10	23	43.48	N/D	2	4	50.0
Total	65	112	58.0	Total	76	134	56.72	Total	48	87	55.17

Table 5.3.24 Prevalence of ante-mortem tooth loss by individuals affected in relation to individuals with at least one tooth socket observable (n=number of individuals with ante-mortem tooth loss, N=number of individuals observable, F=females, M=males, N/D=adults of undetermined sex).

Table 5.3.25 summarizes the results for pooled samples from both countries (individuals count). Chi-squared tests revealed no statistically significant differences between female and male prevalence rates within the countries (British samples: χ^2=1.2416, p=0.2652, d.f.=1; German samples: χ^2=0.0978, p=0.7545, d.f.=1). Nevertheless, a high proportion of German individuals with AMTL were of undetermined sex and this might have introduced a certain bias. However, comparing across the countries, statistically significant differences were found, not only for females but also for males (British and German females: χ^2=13.9346, p=0.0000, d.f.=1; British and German males: χ^2=17.0353, p=0.0000, d.f.=1) and when overall frequencies were compared, German individuals suffered significantly more ante-mortem tooth loss than their British contemporaries (χ^2=29.7226, p=0.0000, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
Females	43	118	36.44	Females	95	159	59.75
Males	24	83	28.92	Males	82	143	57.34
N/D	0	9	0.0	N/D	12	31	38.71
Total GB	67	210	31.9	Total D	189	333	56.76

Table 5.3.25 Prevalence of ante-mortem tooth loss for pooled samples by individuals affected in relation to individuals observable (n=number of individuals with ante-mortem tooth loss, N=number of individuals with at least one tooth socket observable, N/D=adults of undetermined sex).

AMTL prevalence by observable tooth sockets is presented in Table 5.3.26. Castledyke South displayed the highest prevalence among the British samples with 8.73 percent of all tooth sockets affected by AMTL. Prevalence at Apple Down was not much lower; here, 7.62 percent of sockets showed signs of remodelling. Only very few tooth sockets were involved at Norton (2.79 percent). Among the German sites, Pleidelsheim had the highest prevalence rate with 13.94 percent of tooth sockets affected. However, the other two sites – Neresheim and Nusplingen – had very similar rates with 12.63 percent and 12.01 percent, respectively.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	132	1214	10.87	F	116	1105	10.5	F	20	552	3.62
M	32	907	3.53	M	48	761	6.31	M	5	283	1.77
N/D	0	31	0.0	N/D	0	13	0.0	N/D	0	62	0.0
Total	164	2152	7.62	Total	164	1879	8.73	Total	25	897	2.79
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
F	192	1464	13.11	F	143	1353	10.57	F	179	1196	14.97
M	137	1089	12.58	M	204	1517	13.45	M	118	896	13.17
N/D	0	51	0.0	N/D	42	369	11.38	N/D	4	68	5.88
Total	329	2604	12.63	Total	389	3239	12.01	Total	301	2160	13.94

Table 5.3.26 Prevalence of ante-mortem tooth loss by tooth sockets affected in relation to tooth sockets observable (n=number of remodelled tooth sockets, N=number of tooth sockets observable, F=females, M=males, N/D=adults of undetermined sex).

	British samples				German samples		
	n	N	%		n	N	%
Females	268	2871	9.33	Females	514	4013	12.81
Males	85	1951	4.36	Males	459	3502	13.11
N/D	0	106	0.0	N/D	46	488	9.43
Total GB	353	4928	7.16	Total D	1019	8003	12.73

Table 5.3.27 Prevalence of ante-mortem tooth loss for pooled samples by tooth sockets affected in relation to tooth sockets observable (n=number of remodelled sockets, N=number of tooth sockets observable, N/D=adults of undetermined sex).

A summary of the previous results is presented in Table 5.3.27. Corresponding to the frequencies obtained for the individual count method, German samples also displayed higher AMTL prevalence rates when available tooth sockets were analysed. While only 7.16 percent of all British tooth sockets were affected by AMTL, a total of 12.73 percent of German tooth sockets displayed various stages of remodelling. Differences in rates occurred between British females and males; more than twice as many tooth sockets from women than men were affected (9.33 percent and 4.36 percent, respectively). No such difference was found in the German samples; here, male tooth sockets had slightly more AMTL but, again, a high number of sockets belonged to individuals of undetermined sex.

The age-related prevalence of AMTL is tabulated in Table 5.3.28 and Fig. 5.3.10. While young adults in both countries had the lowest prevalence, a sharp rise to almost 50.0 percent (49.6 percent) occurred in young-middle aged German adults. Highest rates for both countries were reached in the old adult age class, where close to 80.0 percent (79.49 percent) were affected in the pooled German samples and only slightly less in the pooled British samples (78.26 percent). This more steady increase in AMTL prevalence in the British sites is also depicted in Fig. 5.3.10. In all age categories, German individuals had a higher prevalence than their British counterparts and these high rates were also reached at an earlier age.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	1	40	2.5	16-25	3	31	9.68
26-35	15	63	23.81	26-35	62	125	49.6
36-45	28	67	41.79	36-45	72	94	76.6
45+	18	23	78.26	45+	31	39	79.49
Adult	5	17	29.41	Adult	21	44	47.73
Total GB	67	210	31.95	Total D	189	333	56.76

Table 5.3.28 Age-related prevalence of ante-mortem tooth loss by individuals affected in relation to individuals observable per age class (n=number of individuals affected, N=number of individuals observable).

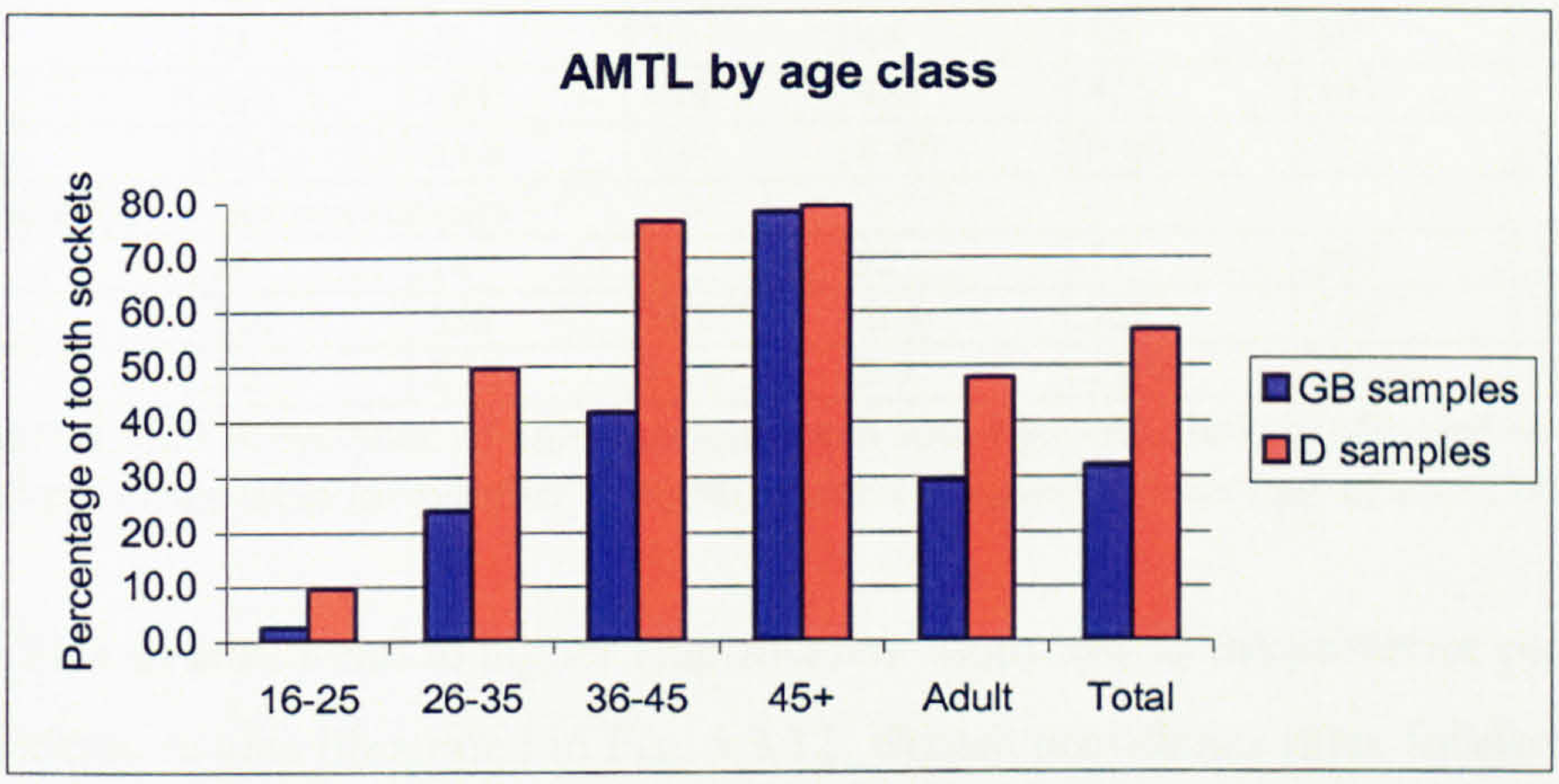


Fig. 5.3.10 Age-related prevalence of ante-mortem tooth loss by individuals affected in relation to individuals observable per age class.

To investigate any possible differences in the tooth sockets affected, Table 5.3.29 was constructed to give information on prevalence rates for individual tooth sockets. In the British maxillae, the first molar was the tooth most often lost ante-mortem (11.54 percent). The second most often lost maxillary tooth was the third molar (6.13 percent).

The same pattern was observed for British mandibles. However, the percentage of lost teeth was much higher than in the maxillae. Almost 16.0 percent (15.94 percent) of mandibular first molars and 14.05 percent of mandibular third molars were lost during life. Prevalence for German maxillary teeth were considerably higher; here, the second molar was the tooth most often falling victim to ante-mortem loss (22.25 percent), followed by the third molar (20.06 percent), although the first molar was almost as frequently lost (19.82 percent). In German mandibles, a decline in prevalence occurred from the first to the third molar. More than one-third of all mandibular first molars had been lost during life (34.89 percent), almost one-quarter of all second molars (25.27 percent) and a rate slightly below one-quarter was observed for third molars (24.69 percent).

Maxilla	British samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	11	14	12	17	19	33	20	13
N	291	293	303	304	297	286	261	212
%	3.78	4.78	3.96	5.59	6.4	11.54	7.66	6.13
Mandible	British samples							
n	22	13	10	12	29	55	30	43
N	332	342	339	336	338	345	343	306
%	6.63	3.8	2.95	3.57	8.58	15.94	8.75	14.05
Maxilla	German samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	31	33	20	44	46	89	89	62
N	496	494	494	491	476	449	400	309
%	6.25	6.68	4.05	8.96	9.66	19.82	22.25	20.06
Mandible	German samples							
n	29	14	10	22	77	194	138	121
N	550	558	562	564	568	556	546	490
%	5.27	2.51	1.78	3.9	13.56	34.89	25.27	24.69

Table 5.3.29 Prevalence of ante-mortem tooth loss by tooth sockets affected in relation to tooth sockets observable (n=number of tooth sockets affected, N=number of tooth positions present).

This overall trend to higher ante-mortem tooth loss in the posterior part of the dentition is also illustrated in Fig. 5.3.11. British prevalence rates followed a similar distribution for the upper and lower jaws with the exception of the maxillary third molars. While the German posterior teeth are generally more often lost during life, this is especially marked in the mandibular first molar, but this was not mirrored in the maxillary dentition.

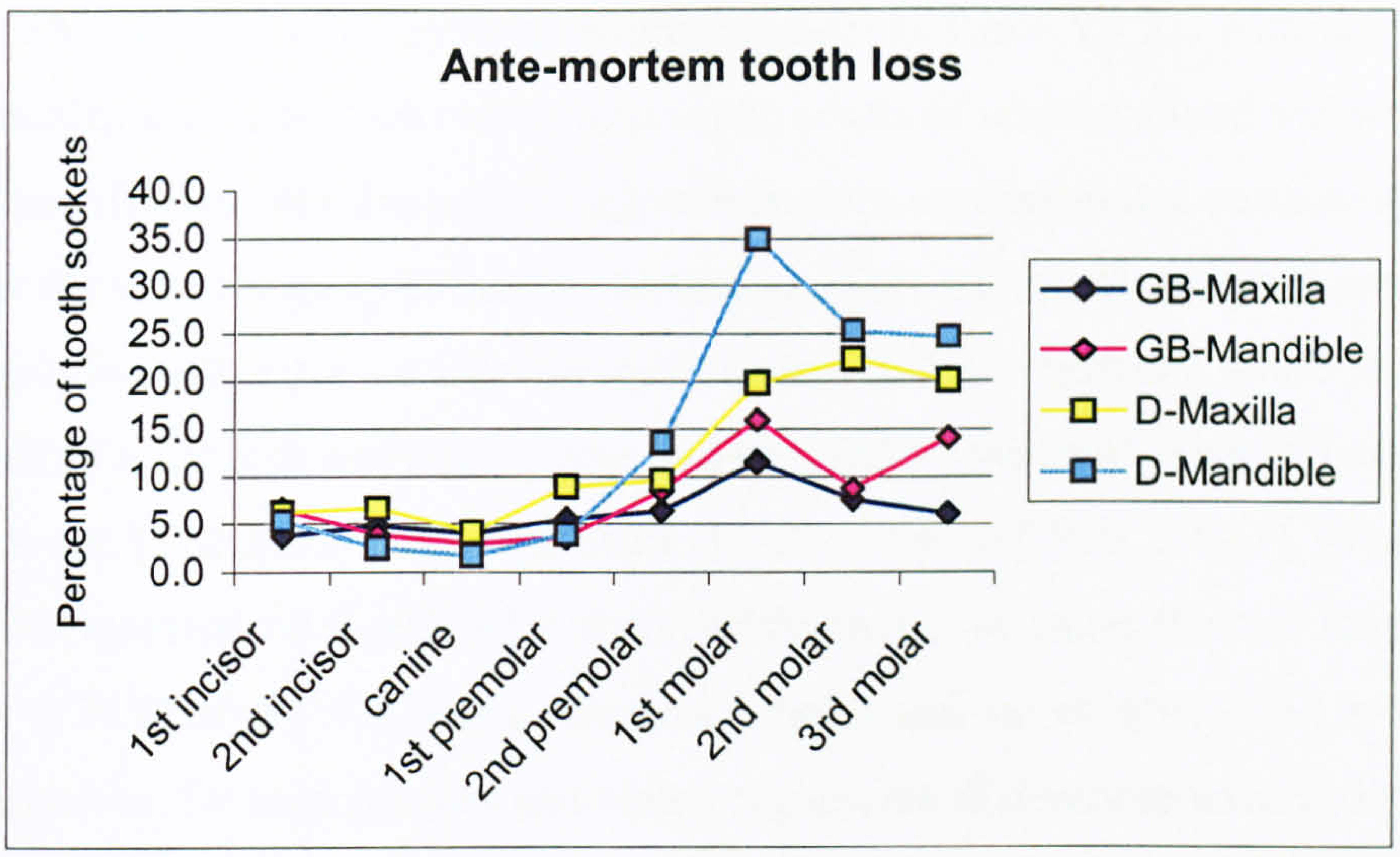


Fig. 5.3.11 Prevalence of ante-mortem tooth loss by tooth positions affected in relation to tooth positions observable.

5.3.5 Periodontal disease

Prevalence rates for periodontal disease (individual count) for all six study samples are presented in Table 5.3.30. At two of the British sites, Apple Down and Castledyke South, more than half of all adults displayed evidence of the disease process (Apple Down: 57.89 percent, Castledyke South: 51.69 percent). At Norton, slightly more than one-quarter were affected, the lowest rate within the study samples (26.67 percent). In comparison, German individuals had experienced much higher frequencies. Periodontal disease was most common at Nusplingen, where 77.61 percent of all individuals were affected. At Pleidelsheim, slightly more than two-thirds (68.97 percent) had experienced alveolar bone reduction and at Neresheim, 67.86 percent were involved.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	28	43	65.12	F	28	50	56.0	F	7	25	28.0
M	16	31	51.61	M	19	36	50.0	M	5	16	31.25
N/D	0	2	0.0	N/D	0	3	0.0	N/D	0	4	0.0
Total	44	76	57.89	Total	46	89	51.69	Total	12	45	26.67
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
F	43	61	70.49	F	42	52	80.77	F	30	46	65.22
M	31	47	65.96	M	45	59	76.27	M	27	37	72.97
N/D	2	4	50.0	N/D	17	23	73.91	N/D	3	4	75.0
Total	76	112	67.86	Total	104	134	77.61	Total	60	87	68.97

Table 5.3.30 Prevalence of periodontal disease by individuals affected in relation to individuals with at least one tooth position observable (n=number of individuals with periodontal disease, N=number of individuals observable, F=females, M=males, N/D=adults of undetermined sex).

Data for pooled samples by country is seen in Table 5.3.31. Although German females and males had very similar rates, adults of undetermined sex were almost as often affected. For this reason, any conclusions on sex-related patterning of the disease for the German samples have to be treated with caution. The overall prevalence of periodontal disease for German individuals was 72.07 percent, while slightly less than half of all British individuals were affected (49.52 percent). This difference was large enough to be statistically significant (χ^2=28.2008, p=0.000, d.f.=1). Within each of the two countries, no significance was reach between the sexes (British females and males: χ^2=0.7130, p=0.3985, d.f.=1; German females and males: χ^2=0.0034, p=0.9538, d.f.=1). However, for both females and males, significant differences were proven between the countries (British and German females: χ^2=9.6948, p=0.0018, d.f.=1; British and German males: χ^2=12.8386, p=0.0003, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
Females	64	118	54.24	Females	115	159	72.33
Males	40	83	48.19	Males	103	143	72.03
N/D	0	9	0.0	N/D	22	31	70.97
Total GB	104	210	49.52	Total D	240	333	72.07

Table 5.3.31 Prevalence of periodontal disease for pooled samples by individuals affected in relation to individuals observable (n=number of individuals with periodontal disease, N=number of individuals with at least one tooth position observable, N/D=adults of undetermined sex).

Data for periodontal disease by affected tooth positions for the six study samples are presented in Table 5.3.32. Among the British sites, Castledyke South yielded the highest prevalence with 57.1 percent of all tooth positions affected. At Apple Down, slightly less than one-third of all tooth positions were involved (30.07 percent) and at Norton, only 12.26 percent of observable tooth positions showed periodontal disease. Nusplingen was the German site with the highest prevalence; here, 61.84 percent of all tooth positions displayed some evidence of periodontitis. At Pleidelsheim, more than half of all tooth positions were involved (55.19 percent) and at Neresheim, a relatively low rate of 23.77 percent was detected.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	407	1214	33.53	F	631	1105	57.1	F	80	552	14.49
M	240	907	26.46	M	380	761	49.93	M	30	283	10.6
N/D	0	31	0.0	N/D	0	13	0.0	N/D	0	62	0.0
Total	647	2152	30.07	Total	1011	1879	57.1	Total	110	897	12.26
	Neresheim				Nusplingen				Pleidelsheim		
	N	N	%		n	N	%		n	N	%
F	339	1464	23.16	F	841	1353	62.16	F	645	1196	53.93
M	272	1089	24.98	M	945	1517	62.29	M	526	896	58.71
N/D	8	51	15.69	N/D	217	369	58.81	N/D	21	68	30.88
Total	619	2604	23.77	Total	2003	3239	61.84	Total	1192	2160	55.19

Table 5.3.32 Prevalence of periodontal disease by tooth positions affected in relation to tooth positions observable (n=number of tooth positions with periodontal disease, N=number of tooth positions observable, F=females, M=males, N/D=adults of undetermined sex).

In Table 5.3.33, a summary for each of the two countries is given. With regard to the number of tooth positions observable, overall periodontal disease prevalence rates between Britain and Germany are not as different as when using the individual count. Less than half of all German tooth positions were affected (47.66 percent), while 35.88 percent of British tooth positions had signs of periodontitis.

	British samples				German samples		
	N	N	%		n	N	%
Females	1118	2871	38.94	Females	1825	4013	45.48
Males	650	1951	33.32	Males	1743	3502	49.77
N/D	0	106	0.0	N/D	246	488	50.41
Total GB	1768	4928	35.88	Total D	3814	8003	47.66

Table 5.3.33 Prevalence of periodontal disease for pooled samples by tooth positions affected in relation to tooth positions observable (n=number of tooth positions with periodontal disease, N=number of tooth positions observable, N/D=adults of undetermined sex).

To investigate the influence of age on the prevalence of periodontal disease, age-specific data for affected individuals is compiled in Table 5.3.34 and Fig. 5.3.12. The British samples displayed a steady rise from the youngest to the oldest age category, with a marked increase between young and young-middle aged adults. The same was observed for the German samples. However, this increase was more prominent, with more than 90.0 percent of individuals affected in the middle age adult class. In the oldest age category (45+ years), more than 90.0 percent of individuals in both countries had experienced periodontal disease.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	2	40	5.0	16-25	5	31	16.13
26-35	27	63	42.86	26-35	82	125	65.6
36-45	45	67	67.16	36-45	85	94	90.43
45+	21	23	91.3	45+	36	39	92.31
Adult	9	17	52.94	Adult	32	44	72.73
Total	104	210	49.52	Total	240	333	72.07

Table 5.3.34 Age-related prevalence of periodontal disease by individuals affected in relation to individuals observable per age class (n=number of individuals affected, N=number of individuals observable).

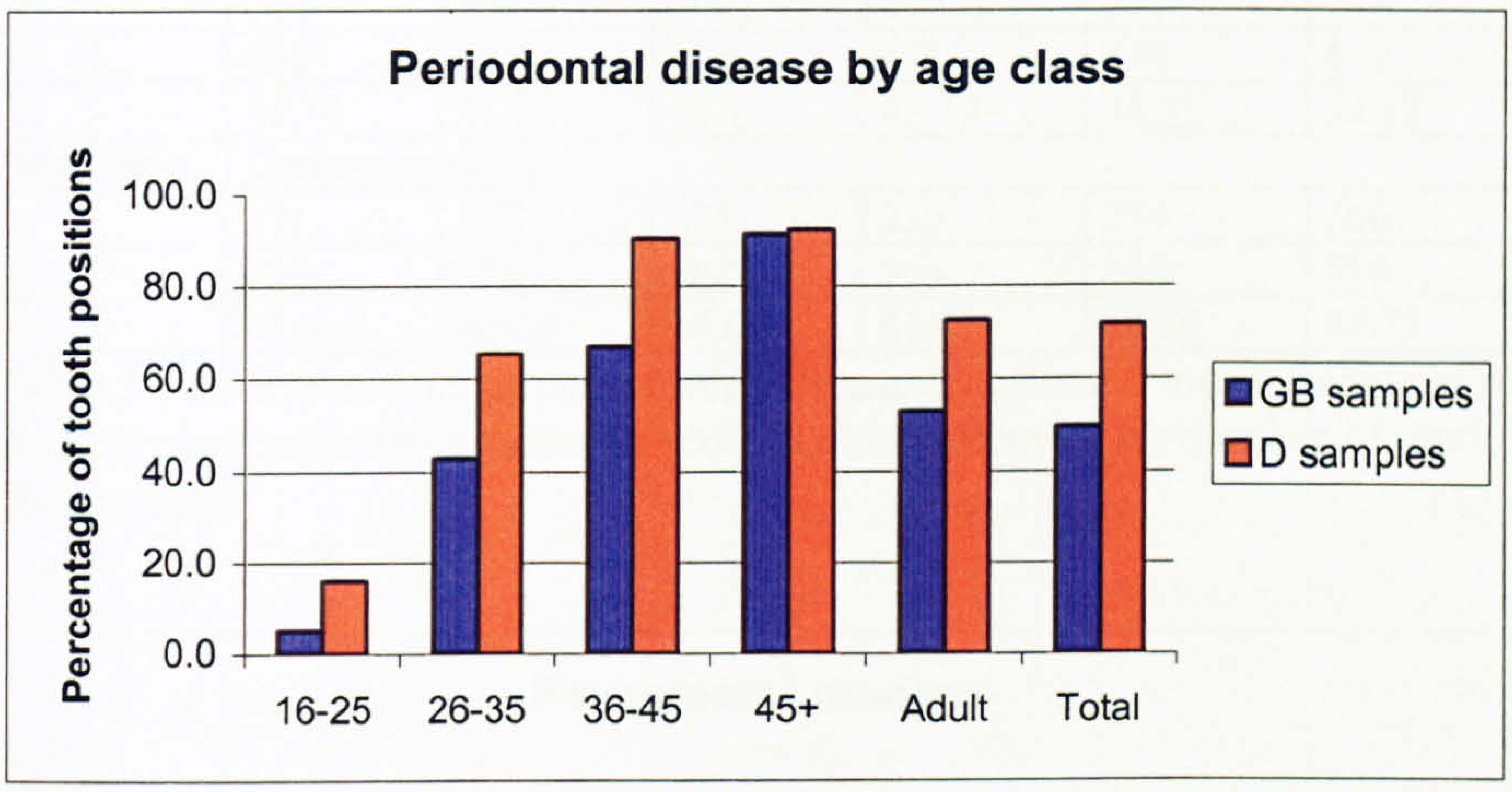


Fig. 5.3.12 Age-related prevalence of periodontal disease by individuals affected in relation to individuals observable per age class.

Table 5.3.35 and Fig. 5.3.13 illustrate prevalence rates for individual tooth positions, separated into upper and lower jaws. In both countries, the molar regions were involved most often; this was observed for the maxilla and mandible. The increase in prevalence from the anterior to the posterior dentition was least prominent in British maxillae. However, German maxillae and mandibles, as well as British lower jaws all showed a noticeable rise in frequency between the second premolar and the first molar.

Maxilla	British samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	88	91	94	99	96	99	92	76
N	291	293	303	304	297	286	261	212
%	30.24	31.06	31.02	32.57	32.32	34.62	35.25	35.85
Mandible	British samples							
n	114	113	112	115	129	166	148	136
N	332	342	339	336	338	345	343	306
%	34.34	33.04	33.04	34.23	38.17	48.12	43.15	44.44
Maxilla	German samples							
	1st incisor	2nd incisor	canine	1st premolar	2nd premolar	1st molar	2nd molar	3rd molar
n	212	207	206	215	213	234	213	157
N	496	494	494	491	476	449	400	309
%	42.74	41.9	41.7	43.79	44.75	52.12	53.25	50.81
Mandible	German samples							
n	231	227	225	235	274	360	319	286
N	550	558	562	564	568	556	546	490
%	42.0	40.68	40.04	41.67	48.24	64.75	58.42	58.37

Table 5.3.35 Prevalence of periodontal disease by affected tooth sockets in relation to all tooth sockets observable (n=number of tooth sockets affected, N=number of tooth sockets observable).

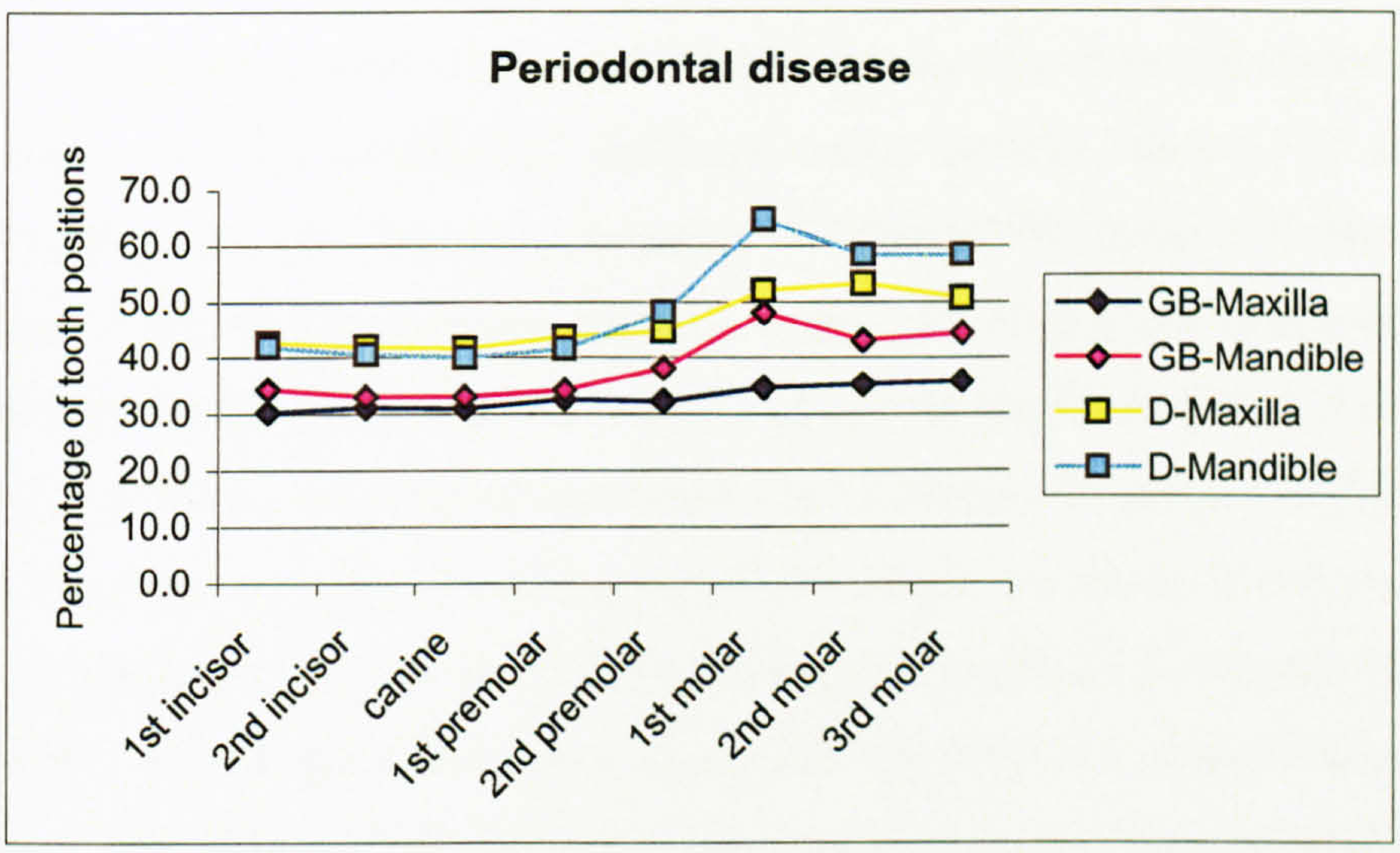


Fig. 5.3.13 Prevalence of periodontal disease by tooth position affected in relation to tooth positions observable (GB=pooled British samples, D=pooled German samples).

5.3.6 Enamel hypoplasia

Enamel hypoplasia – deciduous teeth

Hypoplastic defects on deciduous teeth did not occur in any of the British populations. Of 50 individuals with at least two deciduous teeth observable, none were affected. Prevalence of enamel hypoplasia for the German samples was very low; one subadult dentition was affected at Neresheim (4.35 percent, or 1 of 23 individuals) and one individual had several percent hypoplastic lines at Nusplingen (9.09 percent, or 1 of

11 individuals). A total of 3.77 percent of subadult individuals (2 of 53 individuals) from the German samples had enamel hypoplasia. Expressed as a percentage of affected teeth in relation to the number of observable teeth, none of the 449 observable deciduous teeth from the British samples had hypoplastic defects, while 0.83 percent (4 of 481 deciduous teeth) were affected in the pooled German samples. For individual sites, the prevalence was 1.08 percent (2 of 186 deciduous teeth) at Neresheim and 2.33 percent (2 of 86 deciduous teeth) at Nusplingen. The difference in the number of individuals present and the higher number of teeth in the analysis of enamel hypoplasia as compared to dental caries was caused by the inclusion of teeth that were erupting or not yet erupted.

Enamel hypoplasia – permanent teeth

As for deciduous teeth, numbers of observable permanent teeth were also higher compared to numbers presented in the analysis of dental caries because of the inclusion of teeth that have not fully erupted. The prevalence of enamel hypoplasia for each of the six study samples by affected individuals can be found in Table 5.3.36 and a summary for both pooled populations is presented in Table 5.3.37. Among the British samples, Apple Down had the lowest prevalence with only 7.69 percent of all individuals affected. Castledyke South and Norton had similar frequencies with almost 20.0 percent of skeletons showing hypoplastic defects at Castledyke South and slightly more than 20.0 percent at Norton. At Apple Down, non-adults were most at risk with a prevalence of 12.0 percent, while males had the lowest prevalence (3.23 percent). In contrast, children were affected the least at Castledyke South (4.55 percent) but one-quarter of females had enamel hypoplasia. At Norton, all sub-groups showed similar frequencies, with more than one-quarter of non-adults and males and more than one-fifth of females affected.

Among the German samples, Neresheim yielded almost twice the prevalence than the other two sites. Close to one-fifth of skeletons from Neresheim had experienced enamel growth disruption, while 10.42 percent at Nusplingen and 11.38 percent at Pleidelsheim were affected. Rates for non-adults were similar for all three German sites with almost 15.0 percent showing hypoplastic defects at Neresheim and Pleidelsheim. Almost one-fifth of non-adults from Nusplingen had enamel hypoplasia. Females and males from Neresheim were more than twice as often affected as their counterparts from Nusplingen and Pleidelsheim; approximately one-fifth displayed defects, while prevalence was below 10.0 percent at Nusplingen and Pleidelsheim. However, adults of undetermined sex showed high enamel hypoplasia frequencies and therefore prevalence rates for females and males might have become distorted.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
<16	3	25	12.0	<16	1	22	4.55	<16	6	23	26.09
F	4	46	8.7	F	14	56	25.0	F	6	28	21.43
M	1	31	3.23	M	8	43	18.61	M	5	19	26.32
N/D	0	2	0.0	N/D	1	5	20.0	N/D	0	12	0.0
Total	8	104	7.69	Total	24	126	19.05	Total	17	82	20.73
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
<16	4	28	14.29	<16	3	16	18.75	<16	4	27	14.81
F	13	62	20.97	F	5	52	9.62	F	4	47	8.51
M	8	45	17.78	M	4	54	7.41	M	4	41	9.76
N/D	3	9	33.33	N/D	3	22	13.64	N/D	2	8	25.0
Total	28	145	19.31	Total	15	144	10.42	Total	14	123	11.38

Table 5.3.36 Prevalence of enamel hypoplasia by individuals affected in relation to individuals with at least one permanent tooth observable (n=number of individuals affected, N=number of individuals observable, <16=subadults below the age of 16 years, F=females, M=males, N/D=adults of undetermined sex).

Despite the above described differences in enamel hypoplasia rates for individual sites, data for pooled samples showed many similarities. The overall prevalence for British and German individuals was approximately 15.0 percent and, unsurprisingly, no statistically significant difference was detected (χ^2=0.4969, p=0.4809, d.f.=1). Apart from adults to whom no sex could be assigned, non-adults, females and males in both countries had corresponding frequencies of enamel hypoplasia and no statistically significant differences were found among the sexes within and between the pooled samples (British females and males: χ^2=0.4454, p=0.5045, d.f.=1; German females and males: χ^2=0.3394, p=0.5602, d.f.=1; British and German females: χ^2=1.2436, p=0.2648, d.f.=1; British and German males: χ^2=0.6547, p=0.4185, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
<16	10	70	14.29	<16	11	71	15.49
Females	24	130	18.46	Females	22	161	13.66
Males	14	93	15.05	Males	16	140	11.43
N/D	1	19	5.26	N/D	8	39	20.51
Total GB	49	312	15.71	Total D	57	412	13.83

Table 5.3.37 Prevalence of enamel hypoplasia for pooled samples by individuals affected in relation to individuals with at least one permanent tooth observable (n=number of individuals affected, N=number of individuals with at least one tooth observable, <16=subadults below the age of 16 years, N/D=adults of undetermined sex).

Findings of enamel hypoplasia prevalence observed for individuals were mirrored when the number of teeth observable was taken into consideration (Table 5.3.38). Apple Down showed the lowest frequency, not only of the British samples, with only 2.06 percent of teeth affected. Less than 8.0 percent of teeth from Castledyke South and Norton were similarly affected. However, non-adults from Norton had the highest prevalence of all British samples with close to 15.0 percent displaying enamel hypoplasia.

Nusplingen and Pleidelsheim had the lowest rates among the German samples with less than 5.0 percent of all teeth affected, and almost 8.0 percent showed hypoplastic lines at Neresheim, the highest prevalence of all German samples. However, non-adults from Neresheim were the least affected of all German children (7.49 percent). At Neresheim, males (8.5 percent) were slightly more often affected than females (7.05 percent) and this was also the case at Nusplingen (females: 1.93 percent, males: 3.6 percent), while rates were almost the same for female and male teeth from Pleidelsheim (females: 2.55 percent, males: 2.58 percent).

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
<16	12	421	2.85	<16	8	329	2.43	<16	43	293	14.68
F	24	1019	2.36	F	100	1041	9.61	F	36	464	7.76
M	11	810	1.36	M	65	836	7.78	M	16	344	4.65
N/D	0	33	0.0	N/D	2	57	3.51	N/D	0	112	0.0
Total	47	2283	2.06	Total	175	2263	7.73	Total	95	1213	7.83
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
<16	25	334	7.49	<16	17	170	10.0	<16	37	290	12.76
F	65	922	7.05	F	17	879	1.93	F	25	981	2.55
M	58	682	8.5	M	33	917	3.6	M	18	698	2.58
N/D	11	72	15.28	N/D	17	218	7.8	N/D	13	121	10.74
Total	159	2010	7.91	Total	84	2184	3.85	Total	93	2090	4.45

Table 5.3.38 Prevalence of enamel hypoplasia by teeth affected in relation to teeth observable (n=number of teeth affected, N=number of teeth observable, <16=subadults below the age of 16 years, F=females, M=males, N/D=adults of undetermined sex).

Again, pooled sample frequencies were close to identical in the two countries (Table 5.3.39); 5.5 percent of British teeth and 5.35 percent of German teeth had evidence of enamel hypoplasia. However, German non-adult teeth had slightly higher rates compared to teeth from British non-adults (Germany: 9.95 percent, Britain: 6.04 percent), while teeth from British females had more enamel defects than German females (Britain: 6.34 percent and Germany: 3.85 percent). Male teeth from both countries had similar rates (Britain: 4.62 percent and Germany: 4.75 percent). Obvious differences did exist between unsexed adult teeth, with German samples having ten times more teeth affected (Britain: 0.99 percent and Germany: 9.98 percent).

	British samples				German samples		
	n	N	%		n	N	%
<16	63	1043	6.04	<16	79	794	9.95
Females	160	2524	6.34	Females	107	2782	3.85
Males	92	1990	4.62	Males	109	2297	4.75
N/D	2	202	0.99	N/D	41	411	9.98
Total GB	317	5759	5.5	Total D	336	6284	5.35

Table 5.3.39 Prevalence of enamel hypoplasia for pooled samples by teeth affected in relation to teeth observable (n=number of teeth with enamel hypoplasia, N=number of teeth observable, <16=subadults below the age of 16 years, N/D=adults of undetermined sex).

The age at which defects occurred was calculated and grouped into 6-month periods, ranging from 0.5 years to 5.5 years and the results can be seen in Fig. 5.3.14. Twenty-eight British individuals had mandibular canines preserved, for which 35 enamel defects were measured and 32 German individuals yielded 40 defects, for which measurements were possible. In both countries, the highest number of hypoplastic lines occurred in the 1.5 to 2.0 year age band. In the previous age band (1.0 to 1.5 years), more British than German individuals had obtained their hypoplastic defects. Between the age of 2 and 4.5 years, more teeth from German skeletons displayed enamel hypoplasia, although differences were minimal.

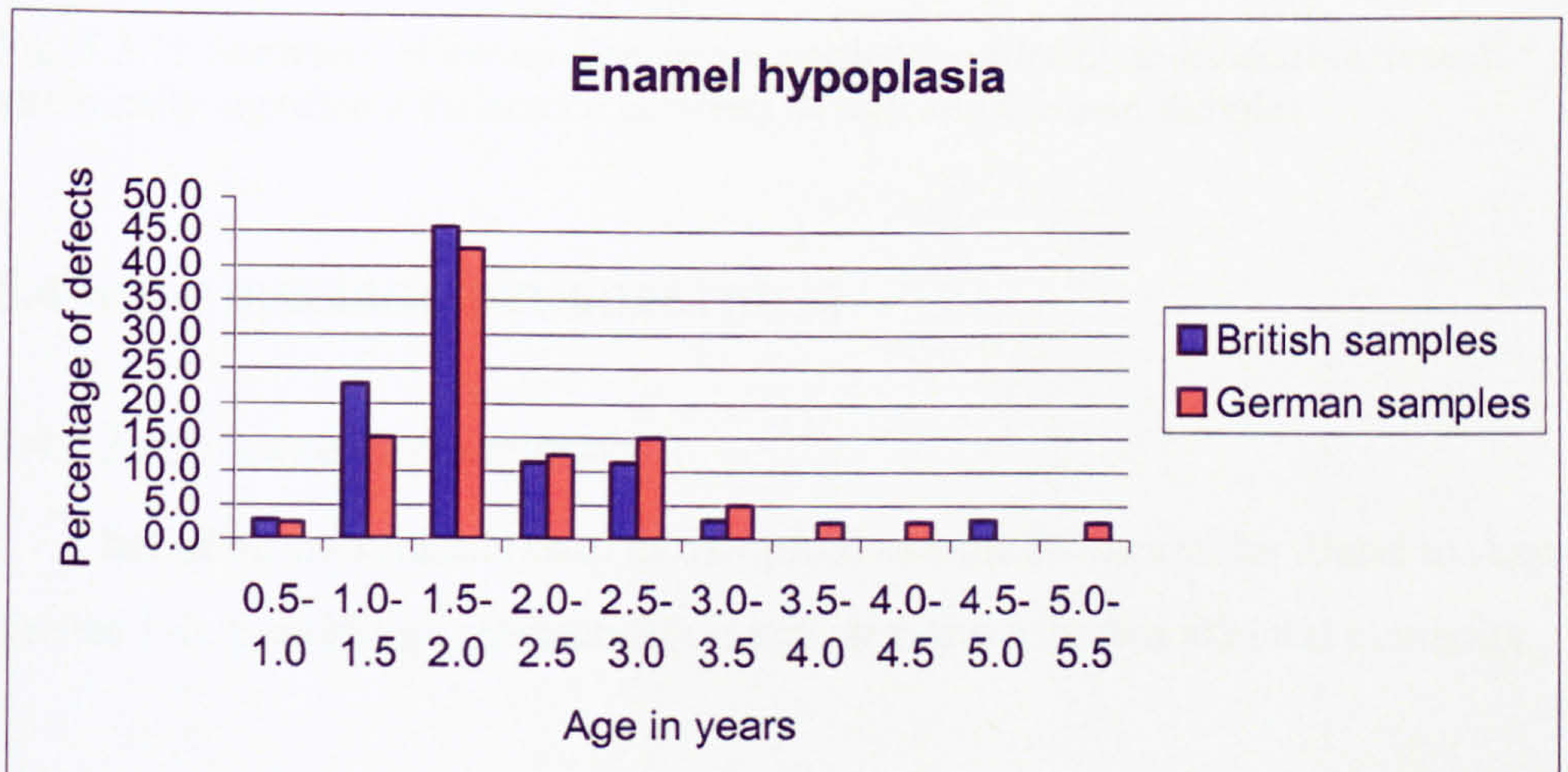


Fig. 5.3.14 Age-at-stress of enamel hypoplastic defects at mandibular canine for pooled samples by 0.5 year intervals.

5.3.7 Summary of dental disease

Fig. 5.3.15 provides an overview of the previously presented results for dental disease. Statistically significant differences in German and British samples were noted for the following conditions: dental caries, periapical lesions, pulp exposure, ante-mortem tooth loss and periodontal disease. In each instance, prevalence was higher in the pooled German samples. However, although dental calculus was more prevalent in the combined British samples, no statistical difference compared to German prevalence was reached. Enamel hypoplasia was also more commonly observed in the British study samples but, again, differences to German frequencies were insignificant.

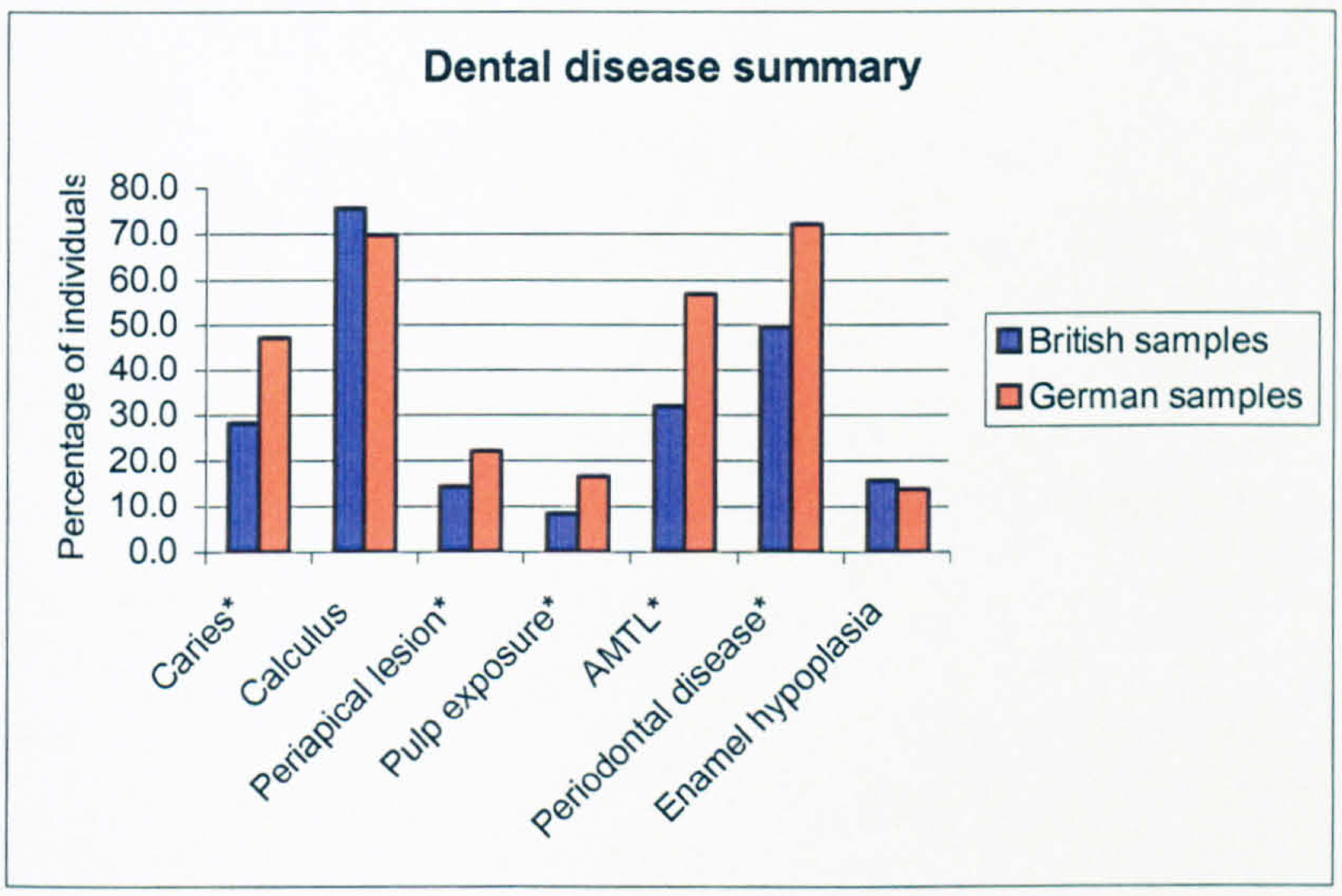


Fig. 5.3.15 Summary of dental disease for pooled samples by individuals affected. * indicates a statistically significant difference between British and German samples.

5.4 JOINT DISEASE (ARTHROPATHIES)

5.4.1 Extra-spinal osteoarthritis

A list of all individuals with extra-spinal osteoarthritis can be found in Appendix C4 Tables 1-6, providing information on age, sex and affected skeletal elements.

Temporo-mandibular joints (TMJ)

Results for osteoarthritis located on the temporo-mandibular joint by number of affected individuals and number of affected joints are summarized in Table 5.4.1. Among the British samples, individuals from Apple Down had the highest percentage of temporo-mandibular joint disease (6.58 percent), followed by Norton (6.25 percent) and

Castledyke South (4.08 percent). Neresheim was the German sample with the highest prevalence (6.67 percent), followed by Nusplingen (4.4 percent). Individuals from Pleidelsheim suffered the least from TMJ disease (1.54 percent). Despite this variation in prevalence, no statistically significant difference between British and German temporo-mandibular joint disease was detected (χ^2=0.3953, p=0.5295, d.f.=1). There was also no statistically significant difference in osteoarthritis prevalence with regard to side, although in both pooled samples, left joints were slightly more often affected (British samples: χ^2=0.0333, p=0.8553, d.f.=1; German samples: χ^2=0.0937, p=0.7596, d.f.=1).

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	5	76	6.58	4	76	5.26	3	73	4.11
Castledyke South	2	49	4.08	0	65	0.0	2	62	3.23
Norton	2	32	6.25	2	42	4.76	0	35	0.0
Total GB	9	157	5.73	6	183	3.28	5	170	2.94
Neresheim	5	75	6.67	4	88	4.55	4	92	4.35
Nusplingen	4	91	4.4	3	102	2.94	2	104	1.92
Pleidelsheim	1	65	1.54	1	74	1.35	1	74	1.35
Total D	10	231	4.33	8	264	3.03	7	270	2.59

Table 5.4.1 Prevalence of temporo-mandibular joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Table 5.4.2 lists prevalence rates for pooled samples by sex. Females in both countries were more often affected than males. British females (7.61 percent) had more than twice as much TMJ disease than their male counterparts (3.17 percent), and a similar frequency was found between German females and males (6.09 percent and 2.73 percent, respectively). However, the number of individuals involved was too small for statistical testing.

Site	British samples				German samples		
	n	N	%		n	N	%
Females	7	92	7.61	Females	7	115	6.09
Males	2	63	3.17	Males	3	110	2.73
N/D	0	2	0.0	N/D	0	6	0.0
Total GB	9	157	5.73	Total D	10	231	4.33

Table 5.4.2 Prevalence of temporo-mandibular joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

Frequencies for pooled samples by age category and individuals affected are tabulated in Table 5.4.3. In the German samples, TMJ disease already affected young-middle aged adults, as well as middle-aged and old adults, while in the British samples only middle-aged and old adults showed evidence of osteoarthritis in this joint.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	25	0.0	16-25	0	21	0.0
26-35	0	54	0.0	26-35	2	96	2.17
36-45	5	53	9.26	36-45	5	72	6.94
45+	4	21	7.55	45+	2	32	6.25
Adult	0	4	0.0	Adult	1	10	10.0
Total GB	9	157	5.73	Total D	10	231	4.33

Table 5.4.3 Age-related prevalence of temporo-mandibular joint disease by individuals affected (n=number of individuals affected, N=number of individuals observable).

Sterno-clavicular joints (SCJ)

Results for sterno-clavicular joint degeneration for individual sites and pooled samples can be found in Table 5.4.4. While at Norton, no evidence for this disease was present, individuals from Apple Down and Castledyke South were affected to a similar extent, with 14.29 percent and 16.48 percent, respectively. Individuals from Neresheim showed a comparable rate; here, 15.15 percent had experienced sterno-clavicular joint disease. Prevalence at Nusplingen and Pleidelsheim was lower, with 4.35 percent and 4.65 percent affected, respectively. Overall frequency of sterno-clavicular joint disease was higher in the pooled British samples (12.64 percent), as opposed to German samples (8.08 percent). However, a chi-squared test revealed no statistically significant difference between the two countries (χ^2=1.0512, p=0.3052, d.f.=1). Right-sided joints in the British samples were less often involved compared to the opposite side. In contrast, right-sided joints were more commonly affected in the German samples.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	7	49	14.29	5	53	9.43	5	56	8.93
Castledyke South	4	26	15.38	3	38	7.89	1	33	3.03
Norton	0	12	0.0	0	23	0.0	0	15	0.0
Total GB	11	87	12.64	8	114	7.02	6	104	5.77
Neresheim	5	33	15.15	1	42	2.38	5	45	11.11
Nusplingen	1	23	4.35	1	29	3.45	1	33	3.03
Pleidelsheim	2	43	4.65	2	50	4.0	2	54	3.7
Total D	8	99	8.08	4	121	3.31	8	132	6.06

Table 5.4.4 Prevalence of sterno-clavicular joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Table 5.4.5 lists differences between female and male individuals for both pooled samples. In both countries, males were approximately twice as often affected by sterno-clavicular joint disease than females. British males had the highest prevalence, with 18.18 percent of skeletons involved, while 9.43 percent of British females were affected. German females were the least involved; 5.45 percent of female skeletons had OA of the sterno-clavicular joint and 11.9 percent of German males experienced osteoarthritis of this joint. However, the number of individuals affected was too small to be subjected to statistical testing.

	British samples				German samples		
	n	N	%		n	N	%
Females	5	53	9.43	Females	3	55	5.45
Males	6	33	18.18	Males	5	42	11.9
N/D	0	1	0.0	N/D	0	2	0.0
Total GB	11	87	12.64	Total D	8	99	8.08

Table 5.4.5 Prevalence of sterno-clavicular joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

Age-related prevalence of sterno-clavicular joint disease can be seen in Table 5.4.6. In both countries, a similar rise in disease frequency was observed with advancing age. Young-middle aged adults were only slightly affected in both populations, but middle-aged and especially old adults had a much higher prevalence.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	13	0.0	16-25	0	10	0.0
26-35	1	34	2.94	26-35	2	45	4.44
36-45	4	28	14.29	36-45	2	28	7.14
45+	6	11	54.55	45+	4	11	36.36
Adult	0	1	0.0	Adult	0	5	0.0
Total GB	11	87	12.64	Total D	8	99	8.08

Table 5.4.6 Age-related prevalence of sterno-clavicular joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Acromio-clavicular joints (ACJ)

Results for acromio-clavicular joint degeneration for individual sites and pooled samples can be seen in Table 5.4.7. At Norton, no evidence of acromio-clavicular joint disease was found, but only a small number of individuals had joints preserved. However, at Apple Down, 16.28 percent and one-third of individuals at Castledyke South showed degenerative changes on their acromio-clavicular joints. With the exception of Pleidelsheim, where 10.0 percent of all individuals were affected, frequencies at Neresheim and Nusplingen were high, with 42.31 percent and 35.5 percent of adults involved. Despite the observation that almost twice as many skeletons from the German samples (30.64 percent) had acromio-clavicular osteoarthritis, compared to the pooled British sites (17.74 percent), differences were statistically insignificant (χ^2=2.8142, p=0.0934, d.f.=1). Left-sided joints in the British samples were almost twice as often involved than joints from the opposite side. Differences between side involvements in the German samples were marginal.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	7	43	16.28	7	48	14.58	5	51	9.8
Castledyke South	4	12	33.33	4	23	17.39	1	19	5.26
Norton	0	7	0.0	0	12	0.00	0	13	0.0
Total GB	11	62	17.74	11	83	13.25	6	83	7.23
Neresheim	11	26	42.31	7	32	21.88	8	37	21.62
Nusplingen	6	16	37.5	4	23	17.39	5	21	23.81
Pleidelsheim	2	20	10.0	2	22	9.09	1	34	2.94
Total D	19	62	30.64	13	77	16.88	14	92	15.22

Table 5.4.7 Prevalence of acromio-clavicular joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Prevalence of acromio-clavicular joint disease by sex is tabulated in Table 5.4.8. British females had twice as much joint degeneration when compared to their male contemporaries (22.86 percent and 11.11 percent). In contrast, German men were more then twice as often affected than German women (43.75 percent and 17.25 percent) and this difference was of statistically significant magnitude (χ^2=4.9848, p=0.0255, d.f.=1). However, no statistical test could be performed to test for statistical significance between British females and males due to the small sample size. The difference in female prevalence was non-significant (χ^2=0.3090, p=0.5782, d.f.=1). However, German males had a statistically significant higher prevalence compared to their British counterparts (χ^2=7.6057, p=0.0058, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
Females	8	35	22.86	Females	5	29	17.24
Males	3	27	11.11	Males	14	32	43.75
N/D	0	0	0.0	N/D	0	1	0.0
Total GB	11	62	17.74	Total D	19	62	30.64

Table 5.4.8 Prevalence of acromio-clavicular joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

Age-related prevalence of sterno-clavicular joint disease can be found in Table 5.4.9. Only middle-aged and to a greater extent old adults were affected in the British samples; the same age-related increase was seen in the German samples, although here it started earlier in the young-middle aged category.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	9	0.0	16-25	0	7	0.0
26-35	0	26	0.0	26-35	2	20	10.0
36-45	6	18	33.33	36-45	10	22	45.45
45+	4	7	57.14	45+	7	11	63.64
Adult	1	2	50.0	Adult	0	2	0.0
Total GB	11	62	17.74	Total D	19	62	30.65

Table 5.4.9 Age-related prevalence of acromio-clavicular joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Gleno-humeral joints (shoulder joints)

Prevalence of gleno-humeral joint disease can be accessed in Table 5.4.10. Among British sites, frequency rates were high at Castledyke South and Norton, with 21.28 percent and 17.39 percent affected, respectively. However, no skeleton from Apple Down showed evidence of the disease. Among German sites, prevalence was highest at Nusplingen (10.3 percent), followed by Neresheim (5.36 percent) and Pleidelsheim (1.85 percent). In total, British individuals showed twice as much osteoarthritis of the gleno-humeral joint (10.77 percent) than German skeletons (5.04 percent). This difference was statistically insignificant (χ^2=3.0679, p=0.0799, d.f.=1). British individuals had both shoulders equally affected, while slightly more right joints were involved in German osteoarthritis of the gleno-humeral joint. However, the number of preserved joints was very small and one female glenoid fossa from Neresheim (NE66) could not be sided.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	0	60	0.0	0	67	0.0	0	67	0.0
Castledyke South	10	47	21.28	6	62	9.68	7	59	11.86
Norton	4	23	17.39	3	28	10.71	2	32	6.25
Total GB	14	130	10.77	9	157	5.73	9	158	5.70
Neresheim	3	56	5.36	0	64	0.00	2	70	2.86
Nusplingen	3	29	10.3	1	41	2.44	2	43	4.65
Pleidelsheim	1	54	1.85	1	64	1.56	1	61	1.64
Total D	7	139	5.04	2	169	1.18	5	174	2.87

Table 5.4.10 Prevalence of gleno-humeral joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Prevalence of gleno-humeral joint disease by sex is listed in Table 5.4.11. British and German males had similar frequencies (7.27 percent and 8.06 percent), while German females were the least affected sub-sample (2.63 percent). British females had experienced the highest prevalence of gleno-humeral OA, with 13.7 percent. However, this value proved to be statistically non-significant when compared to British male prevalence (χ^2=1.3296, p=0.2488, d.f.=1). The difference in German prevalence rates between the two sexes could not be tested due to the low number of affected individuals. Statistical significant values were found between females with British women having experienced more OA of the gleno-humeral joint (χ^2=6.1586, p=0.0130, d.f.=1). Nevertheless, due to the low number of affected male individuals, no chi-squared test could be applied.

	British samples				German samples		
	n	N	%		n	N	%
Females	10	73	13.7	Females	2	76	2.63
Males	4	55	7.27	Males	5	62	8.06
N/D	0	2	0.0	N/D	0	1	0.0
Total GB	14	130	10.77	Total D	7	139	5.04

Table 5.4.11 Prevalence of gleno-humeral joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

Table 5.4.12 demonstrates age-related prevalence of gleno-humeral joint disease for pooled samples by individuals affected. A steady increase in frequency from the young-middle adult to the old adult age category was observed in the German samples. A similar but earlier onset was found in the British samples until middle age. For old adults, the rate dropped noticeably. However, the number of affected individuals was generally low and this decline might have occurred by chance.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	1	20	5.0	16-25	0	14	0.0
26-35	2	48	4.17	26-35	1	57	1.75
36-45	8	40	20.0	36-45	2	41	4.88
45+	2	19	10.53	45+	4	23	17.39
Adult	1	3	33.33	Adult	0	4	0.0
Total GB	14	130	10.77	Total D	7	139	5.04

Table 5.4.12 Age-related prevalence of gleno-humeral joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Elbow joints

Prevalence for elbow joint disease is tabulated in Table 5.4.13. Only a few skeletons in both countries showed evidence of osteoarthritis at this specific joint. Among the British samples, Castledyke South individuals had a prevalence of 5.88 percent and at Apple Down, 2.94 percent of individuals were affected. Nusplingen had the highest frequency of elbow joint disease; here, 7.5 percent of skeletons had evidence of the disease. At Pleidelsheim, 3.64 percent and at Neresheim, 3.45 percent of individuals were affected. Overall frequencies for pooled British sites were 3.45 percent and similarly, 3.8 percent for pooled German sites. Unsurprisingly, no statistically significant difference was present between the two samples (χ^2=0.0264, p=0.8710, d.f.=1). The low number of affected elbow joints hindered the assessment of side prevalence. Tentatively, British skeletons had more left elbows affected, while the contrary was found in the German samples.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	2	68	2.94	2	68	2.94	2	71	2.8
Castledyke South	3	51	5.88	3	70	4.29	1	67	1.49
Norton	0	26	0.0	0	36	0.0	0	34	0.0
Total GB	5	145	3.45	5	174	2.87	3	172	1.74
Neresheim	1	63	1.59	1	76	1.32	1	83	1.2
Nusplingen	3	40	7.5	0	50	0.0	3	57	5.26
Pleidelsheim	2	55	3.64	0	67	0.00	2	60	3.33
Total D	6	158	3.8	1	193	0.52	6	200	3.0

Table 5.4.13 Prevalence of elbow joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Table 5.4.14 provides information on elbow joint disease by sex. In both countries, more males than females had degenerative changes at this joint. German males (5.71 percent) were more often affected than any other sub-sample; British males (3.28 percent) had the second highest prevalence, while British and German females shared a similar rate (2.6 percent and 2.41 percent).

	British samples				German samples		
	n	N	%		n	N	%
Females	2	77	2.6	Females	2	83	2.41
Males	2	61	3.28	Males	4	70	5.71
N/D	1	7	14.28	N/D	0	5	0.0
Total GB	5	145	3.45	Total D	6	158	3.8

Table 5.4.14 Prevalence of elbow joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

Age-related prevalence for elbow joint disease can be seen in Table 5.4.15. Middle-aged and old adult British individuals had a similar prevalence, as did young-middle and middle-aged adults in the German samples. No increase in prevalence was noticeable for the study samples. However, the number of affected individuals was low and three skeletons could not be assigned to a specific age category.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	23	0.0	16-25	0	15	0.0
26-35	0	53	0.0	26-35	2	65	3.08
36-45	3	47	6.38	36-45	2	44	4.55
45+	1	16	6.25	45+	0	22	0.0
Adult	1	6	16.67	Adult	2	12	16.67
Total GB	5	145	3.45	Total D	6	158	3.8

Table 5.4.15 Age-related prevalence of elbow joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Wrist joints

Prevalence for wrist joint disease can be found in Table 5.4.16. At Castledyke South, 8.89 percent of individuals had osteoarthritis of the wrist joint. Fewer skeletons were affected at Apple Down; here, 4.41 percent of individuals were involved. Elbow joint disease was not observed at Norton. With 9.52 percent of affected individuals, Nusplingen had the highest prevalence, followed by Neresheim (5.41 percent) and Pleidelsheim (2.56 percent). In total, in both countries similar frequencies were present; 5.22 percent in British and 5.15 percent in German samples. Again, no statistical significance was detected (χ^2=0.0005, p=0.9813, d.f.=1). Among the British sites, more wrist joints of the left side were affected; in contrast, German skeletons displayed more osteoarthritis of the right wrist joint.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	3	68	4.41	3	71	4.23	0	69	0
Castledyke South	4	45	8.89	2	56	3.57	2	63	3.17
Norton	0	21	0.0	0	28	0.0	0	28	0.0
Total GB	7	134	5.22	5	155	3.23	2	160	1.25
Neresheim	2	37	5.41	0	48	0.0	2	54	3.7
Nusplingen	2	21	9.52	0	31	0.0	2	39	5.13
Pleidelsheim	1	39	2.56	1	55	1.82	1	50	2.0
Total D	5	97	5.15	1	134	0.75	5	143	3.5

Table 5.4.16 Prevalence of wrist joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Table 5.4.17 lists prevalence for wrist joint disease by sex. German males displayed the highest frequency with 9.76 percent of skeletons affected, followed by British males (6.67 percent). British females (4.29 percent) and German females (1.85 percent) had their wrist joints less often involved.

	British samples				German samples		
	n	N	%		n	N	%
Females	3	70	4.29	Females	1	54	1.85
Males	4	60	6.67	Males	4	41	9.76
N/D	0	4	0.0	N/D	0	2	0.0
Total GB	7	134	5.22	Total D	5	97	5.15

Table 5.4.17 Prevalence of wrist joint disease by affected individuals for pooled samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

Age-related prevalence of wrist joint disease is tabulated in Table 5.4.18. In both countries, only middle-aged and old adults were affected, with old adults showing a consistently higher prevalence. Nevertheless, the low number of individuals with wrist joint disease might be responsible for this result.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	19	0.0	16-25	0	9	0.0
26-35	0	48	0.0	26-35	0	38	0.0
36-45	4	44	9.09	36-45	2	32	6.25
45+	3	16	18.75	45+	2	15	13.33
Adult	0	7	0.0	Adult	1	3	33.33
Total GB	7	134	5.22	Total D	5	97	5.15

Table 5.4.18 Age-related prevalence of wrist joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Hand joints

Table 5.4.19 provides information on osteoarthritis of the hands. At Castledyke South, a total of 17.95 percent of adult individuals displayed degenerative changes at this joint complex. Prevalence for Apple Down and Norton was the same; here, 14.29 percent of individuals were affected, respectively. One-fifth of adult individuals from Neresheim showed osteoarthritis of the hands, as well as 12.5 percent of skeletons from Nusplingen and 9.38 percent of individuals from Pleidelsheim. Overall prevalence between the pooled samples was similar, although slightly higher in the British samples with 15.45 percent of individuals involved as opposed to 14.29 percent of German skeletons. However, this difference was negligible and not statistically significant

(χ^2=0.0471, p=0.8281, d.f.=1). In both pooled samples, right hands were more often affected than left hands.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	10	70	14.29	7	70	10.0	6	68	8.82
Castledyke South	7	39	17.95	1	46	2.17	7	54	12.96
Norton	2	14	14.29	1	20	5.0	2	17	11.77
Total GB	19	123	15.45	9	136	6.62	15	139	10.79
Neresheim	6	30	20.0	1	39	2.56	5	42	11.9
Nusplingen	1	8	12.5	0	12	0.0	1	16	6.25
Pleidelsheim	3	32	9.38	0	45	0	3	41	7.32
Total D	10	70	14.29	1	96	1.04	9	99	9.09

Table 5.4.19 Prevalence of hand joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Table 5.4.20 provides prevalence rates of osteoarthritis of the hand by sex. At the British sites, males had slightly more hand joint disease (16.0 percent) than British females (15.49 percent). German females had a higher prevalence of OA at this joint complex (15.38 percent) than German males (12.9 percent). However, the number of affected individuals was generally low and the observed differences were minimal. Consequently, no statistically significant differences were found when chi-squared testing was possible (British females and males: χ^2=0.0057, p=0.9398, d.f.=1; German females and males: not testable; British and German females: χ^2=0.0002, p=0.9880, d.f.=1; British and German males: not testable).

	British samples				German samples		
	n	N	%		n	N	%
Females	11	71	15.49	Females	6	39	15.38
Males	8	50	16.0	Males	4	31	12.9
N/D	0	2	0.0	N/D	0	0	0.0
Total GB	19	123	15.45	Total D	10	70	14.29

Table 5.4.20 Prevalence of hand joint disease by affected individuals for pooled samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	21	0.0	16-25	0	11	0.0
26-35	1	40	2.5	26-35	3	23	13.04
36-45	13	42	30.95	36-45	3	26	11.54
45+	4	15	26.67	45+	3	9	33.33
Adult	1	5	20.0	Adult	1	1	100.0
Total GB	10	123	15.45	Total D	10	70	14.29

Table 5.4.21 Age-related prevalence of hand joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Age-related prevalence of hand joint disease can be found in Table 5.4.21. In both samples, no obvious increase in hand joint disease frequencies was detected, although older individuals had a higher tendency of displaying degeneration of these joints.

Hip joints

Information on prevalence of hip joint disease can be seen in Table 5.4.22. Frequencies among the British sites were relatively uniform, with Castledyke South having the highest rate (23.38 percent), followed by Norton (19.51 percent) and Apple Down (18.57 percent). Among the German sites, Neresheim displayed the highest prevalence (23.17 percent), followed by Nusplingen (14.63 percent). The lowest frequency of all sites was found at Pleidelsheim; here, 7.69 percent showed osteoarthritis of the hip joints. In total, more British than German skeletons displayed hip joint disease (20.74 percent and 15.42 percent). However, no statistically significant value was reached between the two countries (χ^2=1.8643, p=0.1721, d.f.=1). Side involvement was evenly distributed within both countries, although in British samples, right hip joints were slightly more often affected.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	13	70	18.57	11	71	15.49	13	71	18.31
Castledyke South	18	77	23.38	16	89	17.98	13	83	15.66
Norton	8	41	19.51	6	43	13.95	7	46	15.22
Total GB	39	188	20.74	33	203	16.26	33	200	16.5
Neresheim	19	82	23.17	16	89	17.98	14	86	16.28
Nusplingen	6	41	14.63	5	54	9.26	5	53	9.43
Pleidelsheim	6	78	7.69	6	85	7.06	6	79	7.59
Total D	31	201	15.42	27	228	11.84	25	218	11.47

Table 5.4.22 Prevalence of hip joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Table 5.4.23 details hip joint disease prevalence by sex. While British females and males had comparable frequencies (19.64 percent and 22.54 percent), German males were more likely to display hip joint disease when compared to their female counterparts (19.54 percent and 11.61 percent). In the case of hip joint disease, sufficient skeletons were involved to warrant chi-squared analysis. However, differences within and between the countries and sexes were not statistically significant (British females and males: χ^2=0.2209, p=0.6383, d.f.=1; German females and males:

χ^2=2.4069, p=0.1208, d.f.=1; British and German females: χ^2=2.7429, p=0.0977, d.f.=1; British and German males: χ^2=0.2122, p=0.6450, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
Females	22	112	19.64	Females	13	112	11.61
Males	16	71	22.54	Males	17	87	19.54
N/D	1	5	20.0	N/D	1	2	50.0
Total GB	39	188	20.74	Total D	31	201	15.42

Table 5.4.23 Prevalence of hip joint disease by affected individuals for pooled samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

An increase in hip joint disease with advancing age can be seen in Table 5.4.24. However, young adults were not affected in the British samples, while one German individual in the youngest adult age category showed degeneration of this specific joint.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	33	0.0	16-25	1	25	4.0
26-35	11	67	16.42	26-35	6	76	7.89
36-45	15	56	26.79	36-45	14	64	21.88
45+	10	21	47.62	45+	9	27	33.33
Adult	3	11	27.27	Adult	1	9	11.11
Total GB	39	188	20.74	Total D	31	201	15.42

Table 5.4.24 Age-related prevalence of hip joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Knee joints

Prevalence rates for osteoarthritis of the knee joint are tabulated in Table 5.4.25. At Norton, no evidence of the disease was found, although at Apple Down, 4.29 percent and at Castledyke South, 3.75 percent of adult individuals showed osteoarthritis of the knee joint. At Nusplingen, a relatively high frequency of 6.0 percent was seen, while Neresheim and Pleidelsheim had a lower rate, each with 1.28 percent. Overall prevalence was marginally higher for British samples (3.26 percent and 3.42 percent) and results proved to be statistically insignificant (χ^2=0.2464, p=0.6196, d.f.=1). No side preference was observable for British samples, while more right knee joints were affected at German sites. However, the number of individuals with knee joint disease was generally low.

Knee joint disease prevalence by sex is listed in Table 5.4.26. British and German males were less prone to display degenerative changes at this joint (2.74 percent and

1.16 percent). British females (4.0 percent) were almost twice as often affected than British males (2.74 percent) and German females were more than three times more often involved than German males (3.48 percent and 1.16 percent).

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	3	70	4.29	2	72	2.78	3	71	4.23
Castledyke South	3	80	3.75	3	88	3.41	2	89	2.25
Norton	0	34	0.0	0	39	0.0	0	41	0.0
Total GB	6	184	3.26	5	199	2.51	5	201	2.49
Neresheim	1	78	1.28	1	89	1.12	1	86	1.16
Nusplingen	3	50	6.0	1	63	1.59	2	63	3.17
Pleidelsheim	1	78	1.28	0	83	0.0	1	84	1.19
Total D	5	206	2.43	2	235	0.85	4	233	1.72

Table 5.4.25 Prevalence of knee joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

	British samples				German samples		
	n	N	%		n	N	%
Females	4	100	4.0	Females	4	115	3.48
Males	2	73	2.74	Males	1	86	1.16
N/D	0	11	0.0	N/D	0	5	0.0
Total GB	6	184	3.26	Total D	5	206	2.43

Table 5.4.26 Prevalence of knee joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

Table 5.4.27 provides details on age-related knee joint disease prevalence. British individuals with osteoarthritis of their knee joints were increasingly affected in the old adult age category, much more so than in the middle-adult age category. For German individuals, the picture was less clear-cut; here, prevalence was spread between young-middle adults, middle adults and old adults. However, the number of affected individuals was small.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	29	0.0	16-25	0	24	0.0
26-35	0	60	0.0	26-35	3	77	3.9
36-45	3	56	5.36	36-45	1	63	1.59
45+	3	23	13.04	45+	1	25	4.0
Adult	0	16	0.0	Adult	0	17	0.0
Total GB	6	184	3.26	Total D	5	206	2.43

Table 5.4.27 Age-related prevalence of knee joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Ankle joints

Osteoarthritis of the ankle joint was only found at one site (Table 5.4.28). At Castledyke South, 1of 74 individuals had both ankle joints affected (1.35 percent). Overall prevalence for ankle joint disease was low with 0.56 percent. The skeleton involved was that of an old adult female (Tables 5.4.29 and 5.4.30).

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	0	72	0.0	0	72	0.0	0	75	0.0
Castledyke South	1	74	1.35	1	84	1.19	1	86	1.16
Norton	0	33	0.0	0	37	0.0	0	35	0.0
Total GB	1	179	0.56	1	193	0.52	1	196	0.51
Neresheim	0	78	0.0	0	82	0.0	0	92	0.0
Nusplingen	0	50	0.0	0	64	0.0	0	54	0.0
Pleidelsheim	0	82	0.0	0	84	0.0	0	87	0.0
Total D	0	210	0.0	0	230	0.0	0	233	0.0

Table 5.4.28 Prevalence of ankle joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

	British samples				German samples		
	n	N	%		n	N	%
Females	1	95	1.05	Females	0	113	0.0
Males	0	70	0.0	Males	0	86	0.0
N/D	0	14	0.0	N/D	0	11	0.0
Total GB	1	179	0.56	Total D	0	210	0.0

Table 5.4.29 Prevalence of ankle joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	26	0.0	16-25	0	19	0.0
26-35	0	59	0.0	26-35	0	75	0.0
36-45	0	56	0.0	36-45	0	66	0.0
45+	1	21	4.76	45+	0	23	0.0
Adult	0	17	0.0	Adult	0	27	0.0
Total GB	1	179	0.56	Total D	0	210	0.0

Table 5.4.30 Age-related prevalence of ankle joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Foot joints

Prevalence of degenerative joint disease of the feet is tabulated in Table 5.4.31. The highest frequency among British sites was found at Norton (12.5 percent), followed by Castledyke South (10.2 percent) and Apple Down (7.81 percent). At Nusplingen, one-quarter of all adults had osteoarthritis of their feet; exactly twice the frequency of affected individuals from Pleidelsheim (12.5 percent). At Neresheim, 9.62 percent of skeletons had degenerative changes on their foot joints. In total, British samples had a lower frequency, when compared to German samples (9.09 percent and 13.51 percent). However, this difference yielded no statistical significance (χ^2=1.2771, p=0.2584, d.f.=1). Likewise, no side prevalence was found among British individuals, while German individuals had their left feet slightly more often affected than right feet. However, this difference was minimal and one intermediate foot phalanx from a male individual (NU185) could not be sided.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	5	64	7.81	4	67	5.97	2	66	3.03
Castledyke South	5	49	10.2	2	65	3.08	3	61	4.92
Norton	1	8	12.5	1	10	10.0	1	12	8.33
Total GB	11	121	9.09	7	142	4.93	6	139	4.32
Neresheim	5	52	9.62	4	61	6.56	3	63	4.76
Nusplingen	6	24	25.0	4	33	12.12	3	25	12.0
Pleidelsheim	9	72	12.5	7	76	9.21	4	78	5.13
Total D	20	148	13.51	15	170	8.82	10	166	6.02

Table 5.4.31 Prevalence of foot joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

In Table 5.4.32, prevalence of osteoarthritis of the feet is listed by sex. German males displayed the highest frequency (22.6 percent), while British males were less prone to show degenerative changes of the feet (10.64 percent). British and German females had similar frequencies, with 7.35 percent and 7.59 percent. Despite the observed differences, no statistically significant values were obtained when comparing British female and male prevalence (χ^2=0.3778, p=0.5388, d.f.=1). Correspondingly, no statistically significance was reached between British and German females (χ^2=0.0031, p=0.9557, d.f.=1) and British and German males (χ^2=2.6491, p=0.1036, d.f.=1). However, a statistically significant difference was found between German females and males, with males being more often affected (χ^2=6.4088, p=0.0114, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
Females	5	68	7.35	Females	6	79	7.59
Males	5	47	10.64	Males	14	62	22.6
N/D	1	6	16.67	N/D	0	7	0.0
Total GB	11	121	9.09	Total D	20	148	13.51

Table 5.4.32 Prevalence of foot joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

Table 5.4.33 demonstrates age-related frequency rates for osteoarthritis of the feet. A constant rise in prevalence from young-middle adults to old adults was observed for the

British samples. German individuals of all age categories were affected by the disease, but it was much more prevalent in older individuals. However, several skeletons from the German sites could not be assigned to a specific age category.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	0	17	0.0	16-25	1	22	4.55
26-35	1	45	2.22	26-35	2	49	4.08
36-45	3	36	8.33	36-45	6	44	13.64
45+	6	15	40.0	45+	7	19	36.84
Adult	1	8	12.5	Adult	4	14	28.57
Total GB	11	121	9.09	Total D	20	148	13.51

Table 5.4.33 Age-related prevalence of foot joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

Rib joints

Rib joints, or costo-vertebral articulations, cannot be classified as extra-spinal joints. However, movement of the ribs have to be seen mainly in connection with movements of the upper limb and for this reason they will be presented together with other extra-spinal joints. Table 5.4.34 provides detailed information on the prevalence of costo-vertebral joint disease. At Norton, almost half of all adults had evidence of degenerative changes at the rib joints (45.45 percent), while at Apple Down, 18.03 percent, and at Castledyke South, 16.67 percent of individuals showed rib joint degeneration. Neresheim was the site with the highest prevalence rate among German samples; 36.36 percent of skeletons were affected. At Nusplingen, one-quarter of all adults had rib joint osteoarthritis and at Pleidelsheim, 21.05 percent of individuals were involved. Overall prevalence was higher for pooled German sites (29.07 percent) than for British samples (22.4 percent). However, this difference was not statistically significant (χ^2=1.2050, p=0.2723, d.f.=1). Slightly more ribs were affected on the right side of British individuals, while no side prevalence was found among German skeletons. One rib from Norton belonging to a young-middle age male individual (NT12-1) could not be sided, and had to be excluded when prevalence by body side was calculated.

Site	Individuals			Left side			Right side		
	n	N	%	n	N	%	n	N	%
Apple Down	11	61	18.03	30	692	4.34	24	674	3.56
Castledyke South	7	42	16.67	5	585	0.85	8	540	1.48
Norton	10	22	45.45	9	235	3.83	13	248	5.24
Total GB	28	125	22.4	44	1512	2.9	45	1462	3.08
Neresheim	16	44	36.36	17	493	3.45	15	506	2.96
Nusplingen	1	4	25.0	0	115	0.0	1	109	0.92
Pleidelsheim	8	38	21.05	7	441	1.59	6	437	1.37
Total D	25	86	29.07	24	1049	2.29	22	1052	2.09

Table 5.4.34 Prevalence of rib joint disease (n=number of individuals/joints affected, N=number of individuals/joints preserved, Total GB=pooled British samples, Total D=pooled German samples).

Prevalence of rib joint disease by sex can be found in Table 5.4.35. British females had almost twice as much osteoarthritis on their rib joints when compared to British males (26.76 percent and 13.73 percent). Nevertheless, this difference was not statistically significant (χ^2=3.0073, p=0.0829, d.f.=1). Among the German sites, frequencies were similar between the sexes (28.85 percent and 30.3 percent) and no statistically significant difference was found (χ^2=0.0206, p=0.8858, d.f.=1). Equally, the difference in female prevalence rates between the two samples was not statistically significant (χ^2=0.0653, p=0.7983, d.f.=1). However, differences in male prevalence between Britain and Germany almost reached statistical significance (χ^2=3.4110, p=0.0648, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
Females	19	71	26.76	Females	15	52	28.85
Males	7	51	13.73	Males	10	33	30.3
N/D	2	3	66.67	N/D	0	1	0.0
Total GB	28	125	22.4	Total D	25	86	29.07

Table 5.4.35 Prevalence of rib joint disease by affected individuals for pooled samples (N/D=adults of undetermined sex).

Prevalence for age-related rib joint osteoarthritis is given in Table 5.4.36. Individuals from all adult age categories were affected from the British sites, and frequencies increased with age. However, to some individuals only 'adult' age could be assigned and this might have distorted the observed rates. This was less likely to be the case for German samples as only one individual with rib osteoarthritis was placed in the 'adult' age category. Among German skeletons, young adults were not affected. However, young-middle adults had a relatively high prevalence, but a larger proportion of older adults displayed degeneration of these joints.

	British samples				German samples		
Age class	n	N	%	Age class	n	N	%
16-25	1	23	4.35	16-25	0	8	0.0
26-35	6	43	13.95	26-35	8	37	21.62
36-45	9	36	25.0	36-45	12	29	41.38
45+	8	19	42.11	45+	4	10	40.0
Adult	4	4	100.0	Adult	1	2	50.0
Total GB	28	125	22.4	Total D	25	86	29.07

Table 5.4.36 Age-related prevalence of rib joint disease by individuals affected per age class (n=number of individuals affected, N=number of individuals observable).

During most movements, joints, especially those of the upper limb, do not act in an isolated way. For example, when lifting an arm, the gleno-humeral, acromio-clavicular and sterno-clavicular, as well as the costo-vertebral joints are involved. To acknowledge this fact, Table 5.4.37 has been constructed to contain information on upper and lower limb joint prevalence for pooled samples. Upper limb joints were defined as sterno-clavicluar, acromio-clavicular, shoulder, elbow, wrist, hand and costo-vertebral joints, while lower limbs included hip, knee, ankle and foot joints. Results are given separately for left and right-sided joints. However, since the same individual could have several joints affected, the overall number of affected individuals was not calculated, because of differential preservation of individual joints. A further breakdown of results into sex and age-specific subgroups was not conducted, since the previous detailed analysis of separate joints did not yield any marked differences between the samples.

Pooled samples	Left side			Right side		
	n	N	%	n	N	%
British samples upper limb joints	91	2331	3.9	86	2278	3.78
British samples lower limb joints	46	737	6.24	45	736	6.11
German samples upper limb joints	46	1839	2.5	69	1892	3.65
German samples lower limb joints	44	863	5.1	39	850	4.59

Table 5.4.37 Prevalence of upper and lower limb joint disease (n=number of joints affected, N=number of joints preserved).

Little difference between left and right-sided joints of the upper limb of British individuals was seen, with 3.9 percent of left joints and 3.78 percent of right joints affected. Likewise, this was found between lower limb joints, where 6.24 percent of left joints and 6.11 percent of right joints were involved. However, joints of the lower limb showed almost twice as much osteoarthritis compared to upper limb joints. A similar, but less apparent trend was observed for German samples. Left joints of the lower limb were twice as likely to display osteoarthritis (5.1 percent of left joints) than upper limb joints of the same side (2.5 percent of left joints). However, the difference between right-sided joints was less marked, with 3.65 percent of right upper limb joints and 4.59 percent of right lower limb joints affected.

Fig. 5.4.1 summarizes the results for extra-spinal osteoarthritis for pooled samples by individuals and Fig.5.4.2 gives prevalence rates by joints affected. Because of the different method of quantifying osteoarthritis of the costo-vertebral articulations, these results were not included. In both countries, almost equal frequencies were found, with one exception. Osteoarthritis of the acromio-clavicular joint was more prevalent in German samples, while the shoulder joint (GHJ) was less likely to display degenerative changes. However, none of these differences was statistically significant, with the exception of osteoarthritis found in German male feet, when compared to German females.

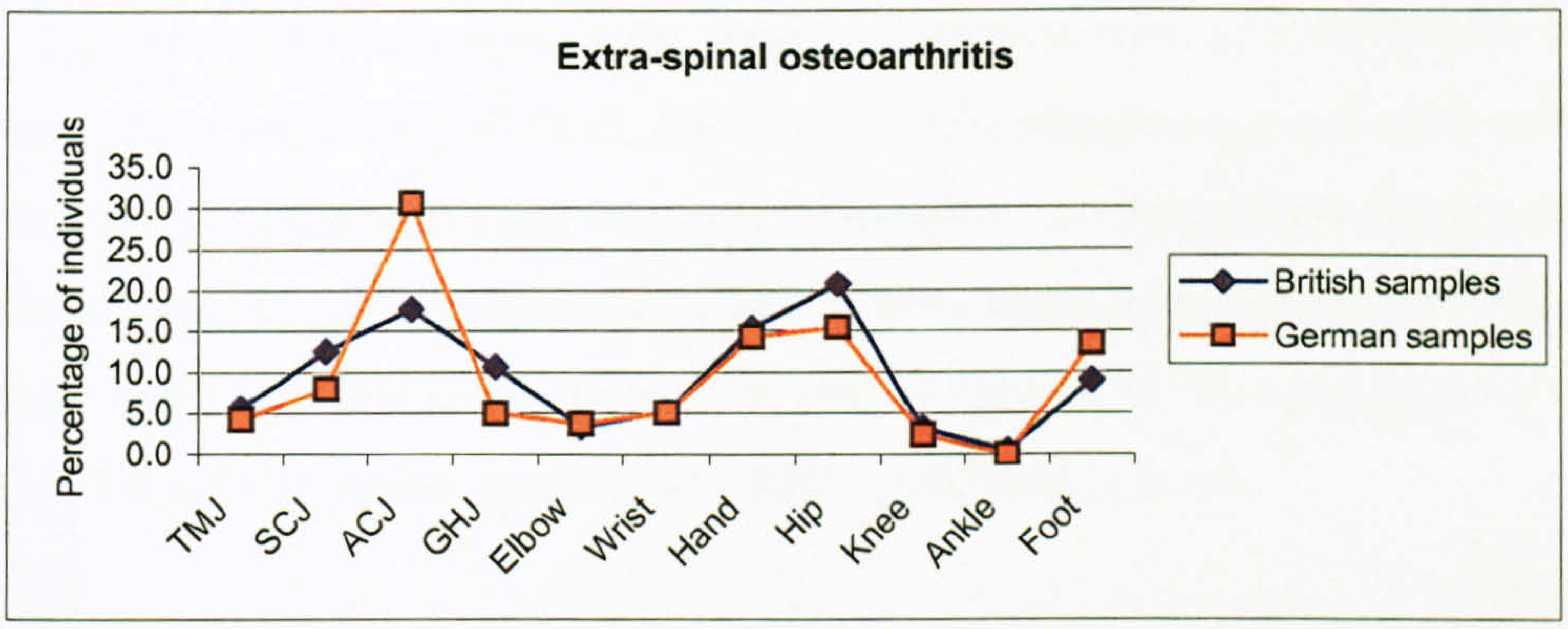


Fig. 5.4.1 Prevalence of extra-spinal osteoarthritis for pooled samples by individuals affected (TMJ=temporo-mandibular joint, SCJ=Sterno-clavicular joint, ACJ=Acromio-clavicular joint, GHJ=Gleno-humeral joint).

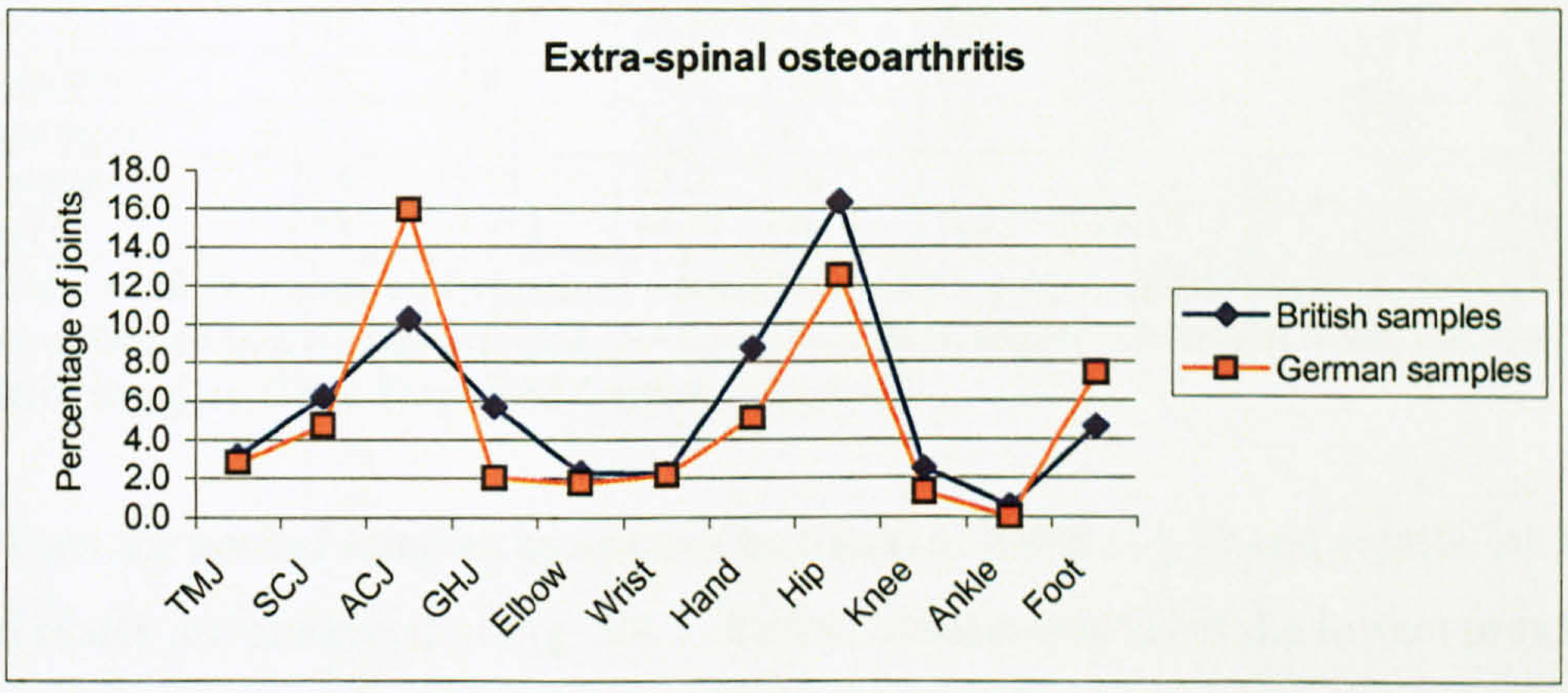


Fig. 5.4.2 Prevalence of extra-spinal osteoarthritis for pooled samples by joints affected (TMJ=temporo-mandibular joint, SCJ=Sterno-clavicular joint, ACJ=Acromio-clavicular joint, GHJ=Gleno-humeral joint).

5.4.2 Vertebral osteoarthritis

Detailed information on vertebral osteoarthritis for each affected individual is listed on CD-ROM, Appendix C4 'Spinal OA'. Prevalence for vertebral osteoarthritis by affected individuals can be seen in Table 5.4.38. Since not all individuals had their vertebral column completely preserved, results were presented separately by cervical, thoracic and lumbar regions. Although some variation between the individual sites occurred, pooled British samples had more osteoarthritis in the cervical spine (22.65 percent), followed by the thoracic vertebrae (16.5 percent). The lumbar spine was the least involved, with 9.0 percent and differences between prevalence of spinal regions were statistically significant (χ^2=13.3884, p=0.0012, d.f.=2). The same order was found for pooled German sites – the cervical spine suffered the most (34.11 percent), while thoracic and lumbar vertebrae had almost equal frequencies, with 24.47 percent and 22.16 percent affected, respectively. Again, differences were of a statistically significant magnitude (χ^2=8.2314, p=0.0163, d.f.=2). The differences between British and German osteoarthritis of the individual vertebral regions were all statistically significant, with German samples having experienced significantly higher numbers of vertebral osteoarthritis (cervical spine: χ^2=6.2728, p=0.01226, d.f.=1; thoracic spine: χ^2=3.7944, p=0.0514, d.f.=1; lumbar spine: χ^2=12.8299, p=0.0648, d.f.=1).

Site	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
Apple Down	20	74	27.03	20	72	27.78	6	70	8.57
Castledyke South	17	67	25.37	6	87	6.9	7	89	7.87
Norton	4	40	10.0	7	41	17.07	5	41	12.2
Total GB	41	181	22.65	33	200	16.5	18	200	9.0
Neresheim	28	82	34.15	20	84	23.81	20	81	24.69
Nusplingen	21	57	36.84	6	30	20.0	9	32	28.13
Pleidelsheim	24	75	32.0	20	74	27.03	12	72	16.67
Total D	73	214	34.11	46	188	24.47	41	185	22.16

Table 5.4.38 Prevalence of vertebral osteoarthritis for specific spinal regions by individual sites (n=number of individuals affected, N=number of individuals preserved, Total GB=pooled British samples, Total D=pooled German samples).

Data for pooled samples by sex can be found in Table 5.4.39 and results for females and males are presented in Fig. 5.4.3. British females displayed the lowest prevalence for cervical and thoracic spines. However, British males had the lowest frequency for osteoarthritis of the lumbar region. Despite these differences, no statistical significance was reached (cervical spine: χ^2=0.9251, p=0.3361, d.f.=1; thoracic spine: χ^2=0.1632, p=0.6862, d.f.=1; lumbar spine: χ^2=2.4834, p=0.1151, d.f.=1). German females and, especially, German males had a higher prevalence of vertebral osteoarthritis in all spinal areas, although German females were consistently less often involved compared to their male counterparts and differences proved to be statistically significant for the thoracic spine, but not for cervical or lumbar spines (cervical spine: χ^2=1.8127, p=0.1782, d.f.=1; thoracic spine: χ^2=5.3400, p=0.0208, d.f.=1; lumbar spine: χ^2=0.2499, p=0.6172, d.f.=1). Furthermore, no statistical significance was found when female prevalence rates were compared between the two countries, although they would have been significant on a lower confidence level (cervical spine: χ^2=3.2474, p=0.0715, d.f.=1; thoracic spine: χ^2=3.7944, p=0.05271, d.f.=1; lumbar spine: χ^2=3.2887, p=0.0698, d.f.=1). However, British and German males had significantly different frequencies at the thoracic and lumbar spines, while differences just missed being significant at the cervical spine (cervical spine: χ^2=3.4092, p=0.0648, d.f.=1; thoracic spine: χ^2=5.2365, p=0.0221, d.f.=1; lumbar spine: χ^2=11.2395, p=0.0008, d.f.=1).

	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
GB Females	19	96	19.79	17	111	15.32	13	110	11.82
GB Males	19	73	26.03	14	80	17.5	4	78	5.13
GB N/D	3	12	25.0	2	9	22.2	1	12	8.33
Total GB	41	181	22.65	33	200	16.5	18	200	9.0
D Females	35	114	30.7	20	108	18.5	22	105	21.0
D Males	38	96	39.6	26	78	33.33	19	79	24.05
D N/D	0	4	0.0	0.0	2	0	0.0	1	0.0
Total D	73	214	34.11	46	188	24.47	41	185	22.16

Table 5.4.39 Prevalence of vertebral osteoarthritis for specific spinal regions by sex (n=number of individuals affected, N=number of individuals preserved, N/D=adults of undetermined sex, Total GB=pooled British samples, Total D=pooled German samples).

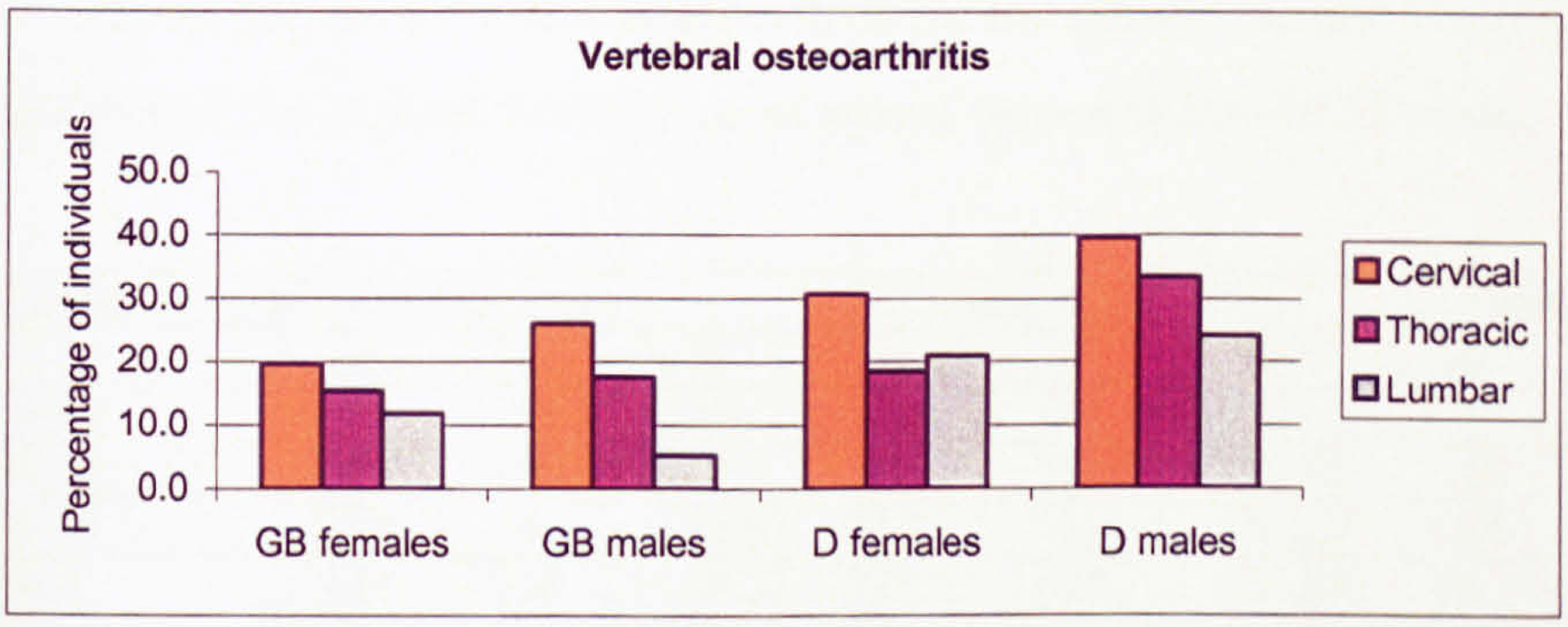


Fig. 5.4.3 Prevalence of female and male vertebral osteoarthritis for pooled samples by individuals affected.

Prevalence of vertebral osteoarthritis for pooled British samples by adult age categories is tabulated in Table 5.4.40 and results are illustrated in Fig. 5.4.4. Thoracic vertebrae showed evidence of osteoarthritis at a younger age, and among young-middle aged adults they were more commonly affected than cervical and lumbar vertebrae.

However, with increasing age the cervical spine displayed a marked increase in OA prevalence. All three spinal regions were most often affected in old adults.

British samples	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
16-25	0	32	0.0	1	35	2.86	0	35	0.0
26-35	3	58	5.17	5	66	7.58	3	63	4.76
36-45	19	54	35.19	14	63	22.22	7	61	11.48
45+	15	25	60.0	10	23	43.48	6	24	25.0
Adult	4	12	33.33	3	13	23.08	2	17	11.76
Total GB	41	181	22.65	33	200	16.5	18	200	9.0

Table 5.4.40 Age-related prevalence of vertebral osteoarthritis for specific spinal regions of pooled British samples (n=number of individuals affected, N=number of individuals preserved).

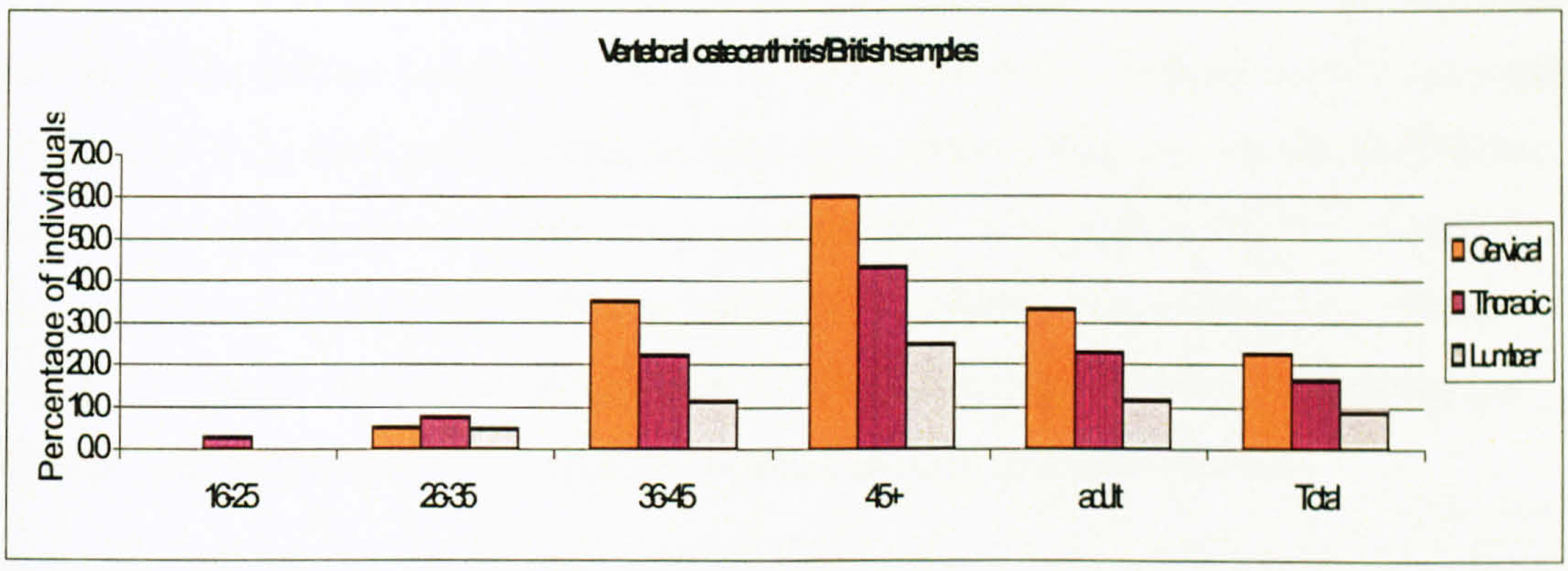


Fig. 5.4.4 Age-related prevalence of vertebral osteoarthritis for pooled British samples by individuals affected.

The same results for German samples can be seen in Table 5.4.41 and Fig. 5.4.5. One young adult had osteoarthritis of the lumbar spine but, apart from this observation, a similar trend was followed as described for the pooled British samples and, again, old adults had the highest prevalence of spinal osteoarthritis in all areas.

German samples	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
16-25	0	25	0.0	0	26	0.0	1	26	3.85
26-35	16	80	20.0	15	72	20.83	10	70	14.29
36-45	31	66	46.97	18	51	35.29	18	57	31.58
45+	24	35	68.57	12	29	41.38	9	26	34.62
Adult	2	8	25.0	1	10	1.0	3	6	50.0
Total D	73	214	34.11	46	188	24.47	41	185	22.16

Table 5.4.41 Age-related prevalence of vertebral osteoarthritis for specific spinal regions of pooled German samples (n=number of individuals affected, N=number of individuals preserved).

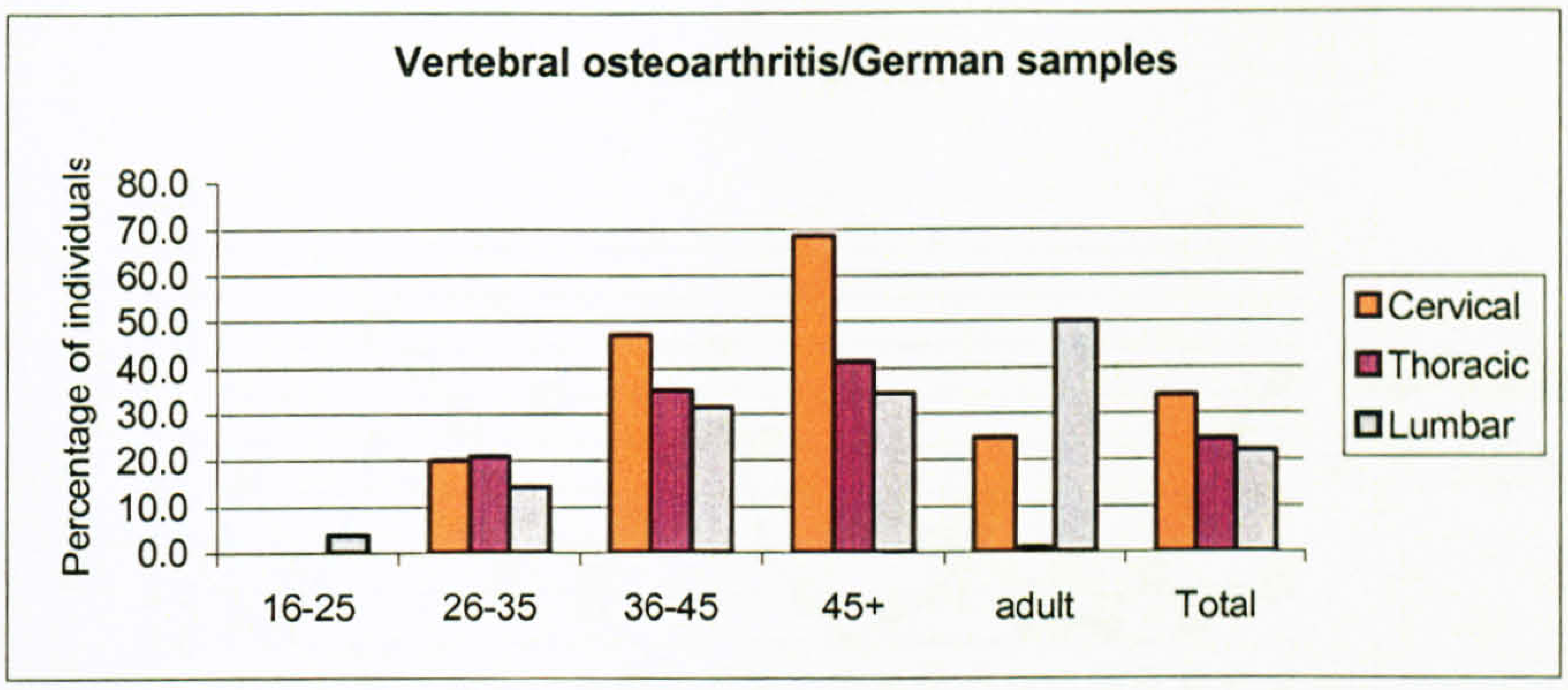


Fig. 5.4.5 Age-related prevalence of vertebral osteoarthritis for pooled German samples by individuals affected.

Prevalence was also calculated for the number of affected facet joints and the results for individual British samples can be found in Table 5.4.42. Contrary to previous results with regard to individuals affected, females from Apple Down and Norton had higher frequencies than males from the same site. However, these differences were small. For pooled British samples, the highest prevalence of vertebral osteoarthritis by affected joints was observed at Castledyke South, (6.3 percent). Apple Down and Norton had very similar prevalence rates, with 3.0 percent and 2.99 percent affected.

	Apple Down			Castledyke South			Norton		
Females	n	N	%	n	N	%	n	N	%
Cervical	44	1102	3.99	27	441	6.12	3	291	1.03
Thoracic	46	1607	2.86	50	1348	3.71	19	586	3.24
Lumbar	16	733	2.18	70	812	8.62	20	275	7.27
Total females	106	3442	3.08	147	2601	5.65	42	1152	3.65
Males	n	N	%	n	N	%	n	N	%
Cervical	56	863	6.49	54	525	10.29	8	140	5.71
Thoracic	25	1274	1.96	88	1122	7.84	11	484	2.27
Lumbar	1	587	0.17	15	527	2.85	4	220	1.82
Total males	82	2724	3.01	157	2174	7.22	23	807	2.85
N/D	n	N	%	n	N	%	n	N	%
Cervical	0	31	0.0	4	53	7.55	0	55	0.0
Thoracic	0	40	0.0	0	62	0.0	0	132	0.0
Lumbar	0	22	0.0	3	45	6.67	0	51	0.0
Total N/D	0	93	0.0	7	160	4.38	0	218	0.0
	n	N	%	n	N	%	n	N	%
Total GB	188	6259	3.0	311	4935	6.3	65	2177	2.99

Table 5.4.42 Prevalence of vertebral osteoarthritis for British sites by affected vertebral facets (n=number of facets affected, N=number of facets preserved, N/D=adults of undetermined sex).

Fig. 5.4.6 presents data for facets joints affected by osteoarthritis by individual vertebrae and by sex. British females had high prevalence rates at C3/4, T4/5 and L5/sacral facets. In contrast, British males had their highest frequencies at C2/3, C7/T1 and T4/5.

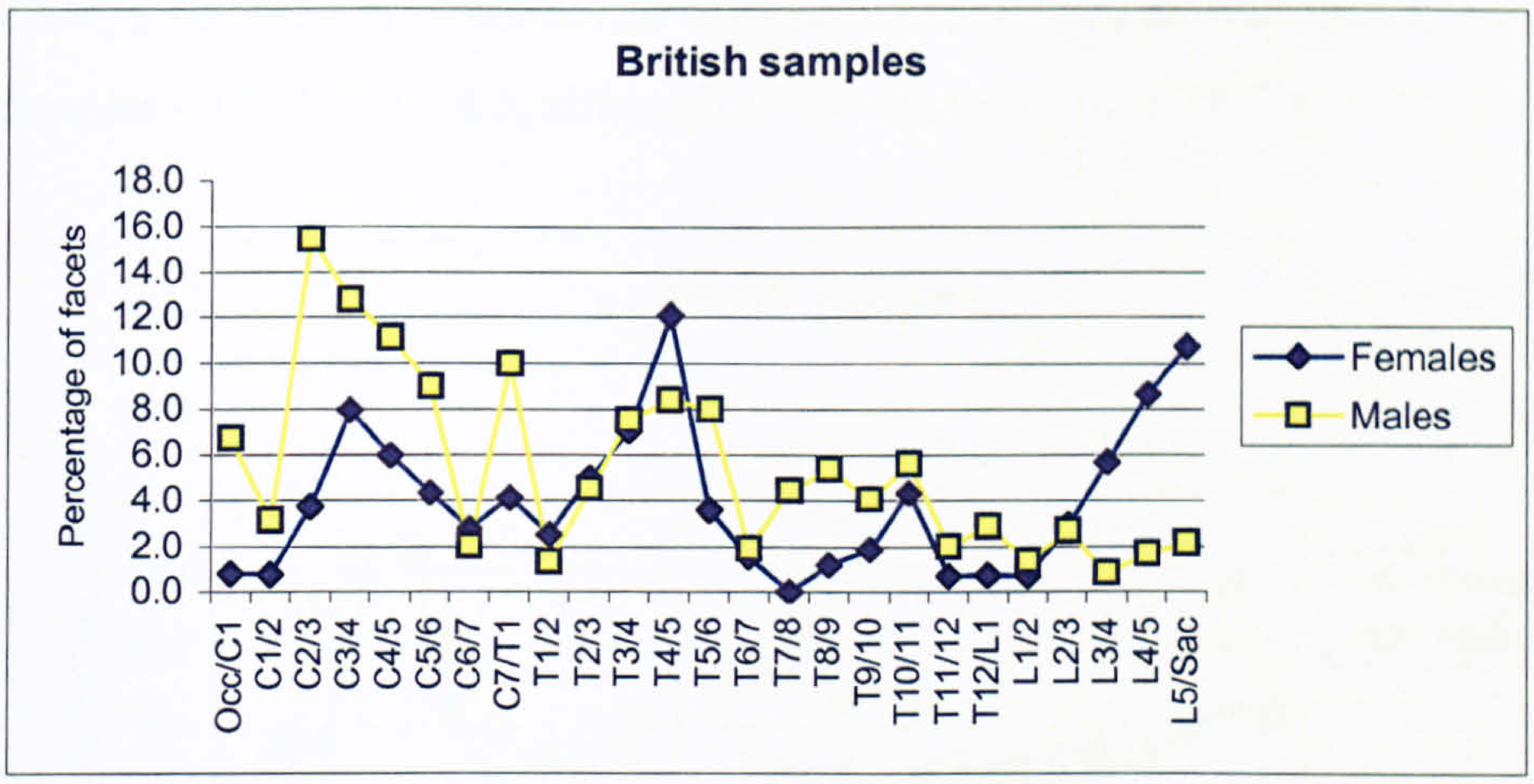


Fig. 5.4.6 Prevalence of vertebral osteoarthritis for pooled British samples by facet joints affected (Occ=occipital condyles, C=cervical vertebra, T=thoracic vertebra, L=lumbar vertebra, Sac=sacral facets).

Results for German samples by facet joints affected can be seen in Table 5.4.43. As for individuals affected, females had less vertebral osteoarthritis of their facet joints than males in all spinal regions. For pooled German samples, the highest prevalence rate was found at Nusplingen, where 6.47 percent (117 of 1,809 joints) were involved, shortly followed by Neresheim, with 6.22 percent (278 of 4,471 joints) and Pleidelsheim with 4.79 percent (230 of 4,804 joints).

	Neresheim			Nusplingen			Pleidelsheim		
Females	n	N	%	n	N	%	n	N	%
Cervical	45	815	5.52	30	365	8.22	32	720	4.44
Thoracic	39	1180	3.31	15	389	3.86	22	1144	1.92
Lumbar	46	604	7.62	11	252	4.37	15	576	2.6
Total females	130	2599	5.0	56	1006	5.57	69	2440	2.83
Males	n	N	%	n	N	%	n	N	%
Cervical	64	578	7.46	42	373	11.26	66	736	8.97
Thoracic	39	858	9.26	9	213	4.23	73	1058	6.9
Lumbar	45	421	10.69	10	169	5.92	22	545	4.04
Total males	148	1857	7.97	61	773	7.89	161	2339	6.88
N/D	n	N	%	n	N	%	n	N	%
Cervical	0	4	0.0	0	26	0.0	0	2	0.0
Thoracic	0	2	0.0	0	0	0.0	0	15	0.0
Lumbar	0	9	0.0	0	4	0.0	0	8	0.0
Total N/D	0	15	0.0	0	30	0.0	0	25	0.0
	n	N	%	n	N	%	n	N	%
Total	278	4471	6.22	117	1809	6.47	230	4804	4.79

Table 5.4.43 Prevalence of vertebral osteoarthritis for German sites by affected vertebral facets (n=number of facets affected, N=number of facets preserved, N/D=adults of undetermined sex).

In Fig. 5.4.7, vertebral osteoarthritis for individual vertebrae is shown separately for German females and males. The three most often affected vertebrae for females were

C3/4, T4/5 and L4/5. Males had high prevalence rates at two vertebrae in common with females – C3/4 and L4/5, although in the thoracic spine T6/7 was involved.

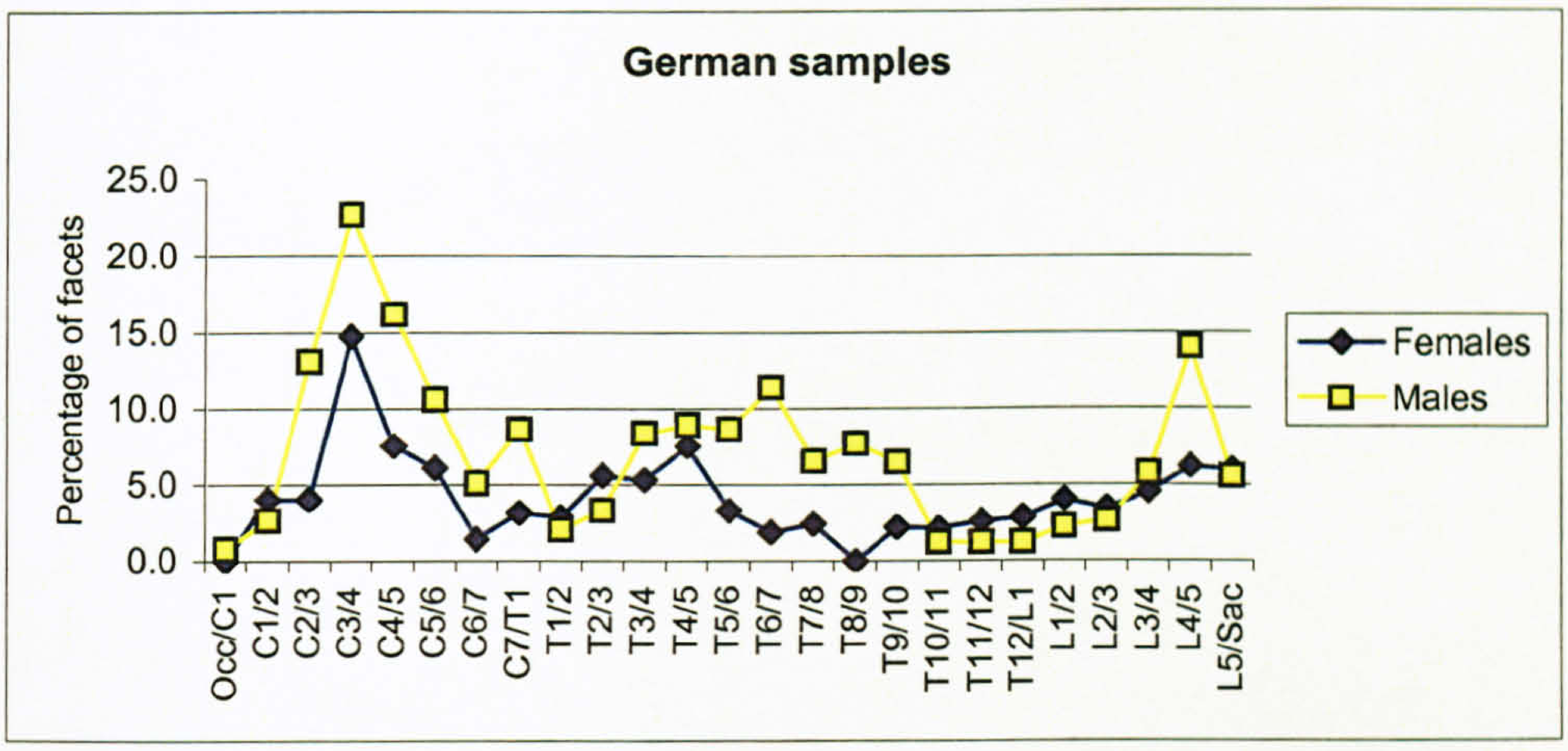


Fig.5.4.7 Prevalence of vertebral osteoarthritis for pooled German samples by facet joints affected (Occ=occipital condyles, C=cervical vertebra, T=thoracic vertebra, L=lumbar vertebra, Sac=sacral facets).

Overall prevalence rates for both pooled samples, by sex and spinal region are tabulated in Table 5.4.44. Although British females had fewer cervical facets affected than British males, a higher frequency was found for female lumbar facets. Pooled data revealed that females and males from British sites had a similar percentage of facet joints involved; 4.1 percent and 4.59 percent. For German samples, males had more osteoarthritis in all of their spinal regions than German females and, consequently, German males also had a higher prevalence of all joints affected (7.45 percent).

	British samples				German samples		
Females	n	N	%	Females	n	N	%
Cervical	74	1834	3.72	Cervical	107	1900	5.63
Thoracic	115	3541	3.25	Thoracic	76	2713	2.8
Lumbar	106	1820	5.82	Lumbar	72	1432	5.03
Total females	295	7195	4.1	Total females	255	6045	4.22
Males				Males			
Cervical	118	1528	7.72	Cervical	172	1687	10.2
Thoracic	124	2880	4.31	Thoracic	121	2129	5.68
Lumbar	20	1334	1.49	Lumbar	77	1135	6.78
Total males	262	5705	4.59	Total males	370	4969	7.45
N/D				N/D			
Cervical	4	139	2.88	Cervical	0	32	0.0
Thoracic	0	234	0	Thoracic	0	17	0.0
Lumbar	3	118	2.54	Lumbar	0	21	0.0
Total N/D	7	471	1.49	Total N/D	0	70	0.0
Total GB	564	13371	4.22	Total D	625	11084	5.64

Table 5.4.44 Prevalence of vertebral osteoarthritis for pooled samples by affected vertebral facets (n=number of facets affected, N=number of facets preserved, N/D=adults of undetermined sex).

The following four figures (Figs. 5.4.8-5.4.11) were designed to analyse any possible differences in left and right side involvement for pooled samples by sex. British females had more left-sided joints affected in the upper cervical spine (C2/3 and C3/4) and more joints of the right side between C4/5-T5/6, with a marked difference at the latter level. Lower lumbar facet joints were slightly more often involved on the right side (L3/4-L5/sacral facets) (Fig. 5.4.8).

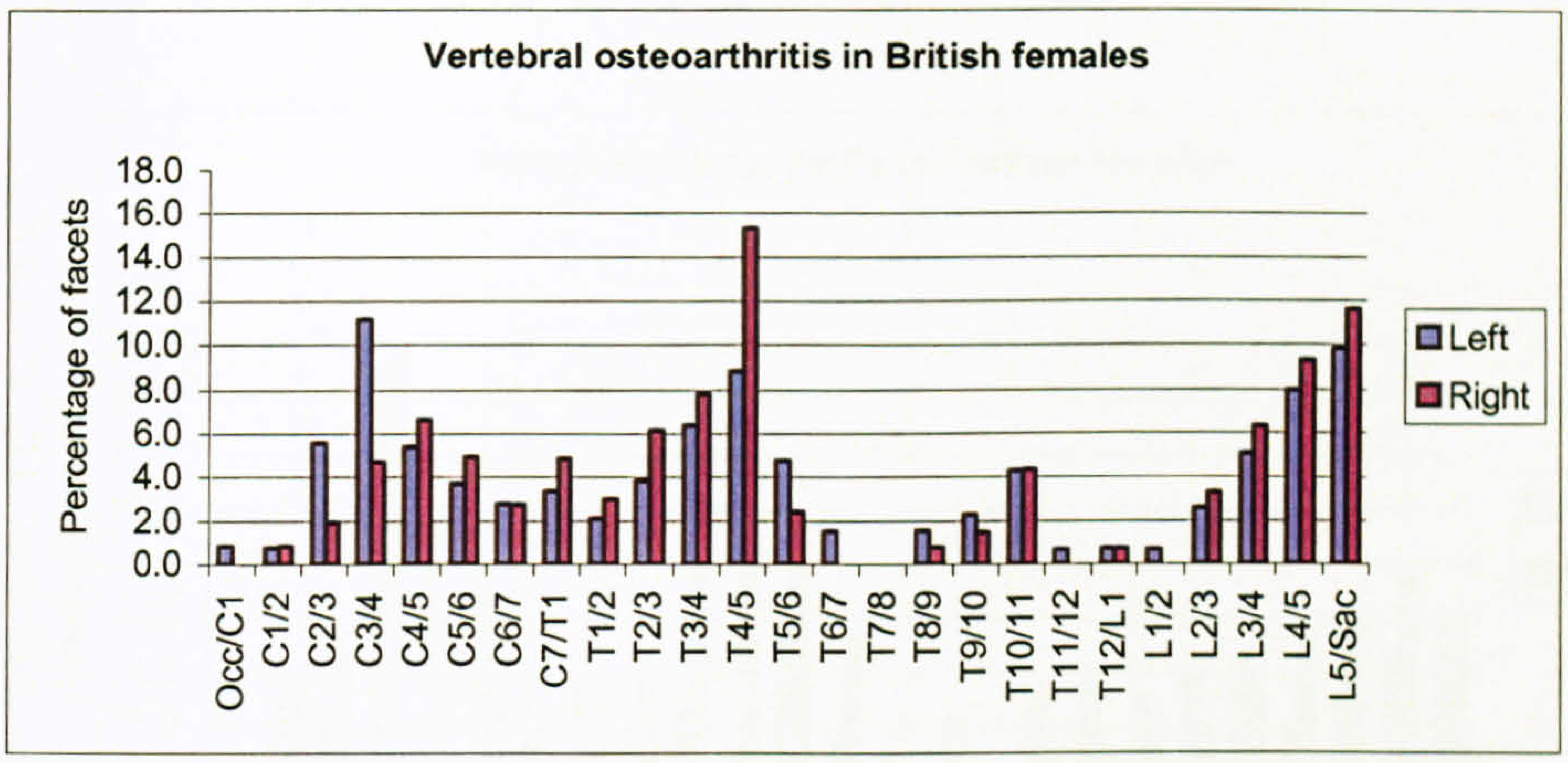


Fig. 5.4.8 Prevalence of vertebral osteoarthritis for British females by side affected (Occ=occipital condyles, C=cervical vertebra, T=thoracic vertebra, L=lumbar vertebra, Sac=sacral facets).

Side distribution for British males was less straightforward (Fig. 5.4.9). Left facets were favoured for most of the cervical spine (C2/3-C5/6), while right facet joints had a slightly higher prevalence at the upper thoracic spine (C7/1-T1/2). Throughout the thoracic vertebral column, left and right side prevalence changed repeatedly, with more left joints involved at the lower thoracic spine (T10/11-T11/12). However, most of the lumbar vertebral facets were affected on the right side (LT12/L1-LL3/4).

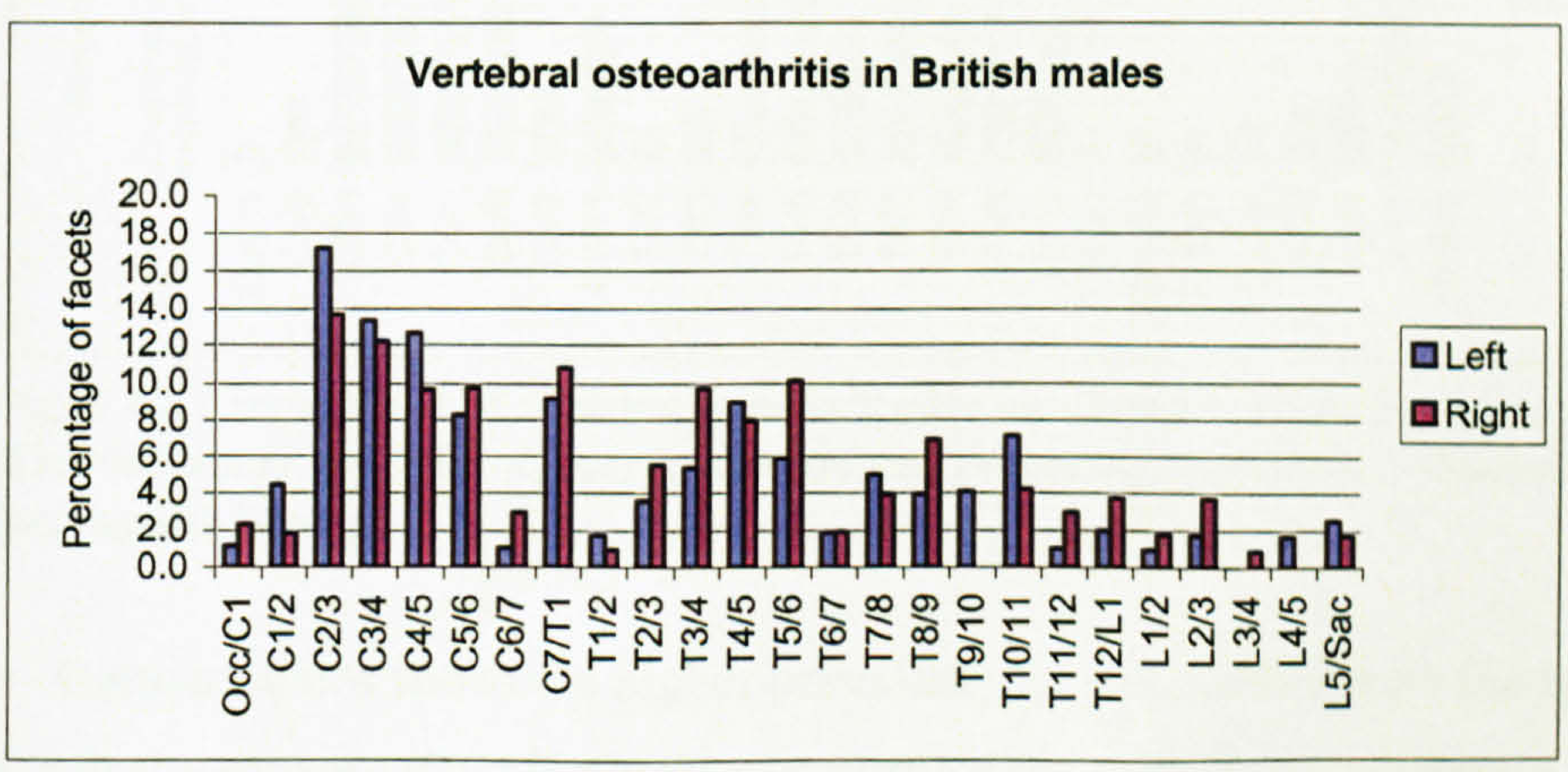


Fig. 5.4.9 Prevalence of vertebral osteoarthritis for British males by side affected (Occ=occipital condyles, C=cervical vertebra, T=thoracic vertebra, L=lumbar vertebra, Sac=sacral facets).

For German females, like British females, left-side facets of the lower cervical column were more often involved (C5/6-C6/7). To a lesser extent, joints of the upper thoracic spine (C7/T1-T1/2) were also more often affected on the left side. Facet joints of the right side showed higher prevalence rates further along the thoracic spine (T2/3-T8/9). At the lower aspect of the thoracic column and the upper lumbar spine, higher prevalence changed to the left side again (T10/11-L2/3), while right-side joints of the lower lumbar vertebrae had more degenerative changes (Fig. 5.4.10).

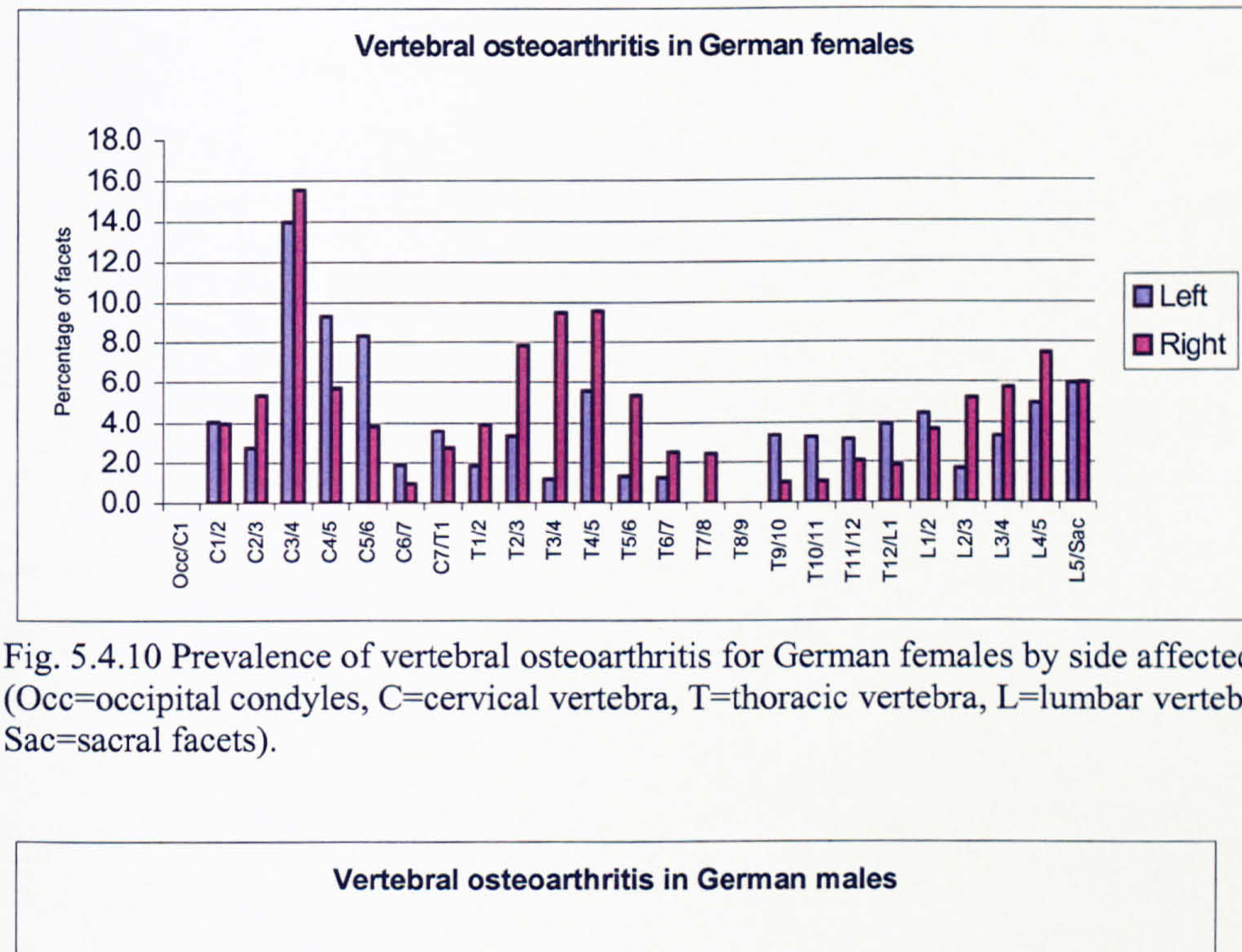


Fig. 5.4.10 Prevalence of vertebral osteoarthritis for German females by side affected (Occ=occipital condyles, C=cervical vertebra, T=thoracic vertebra, L=lumbar vertebra, Sac=sacral facets).

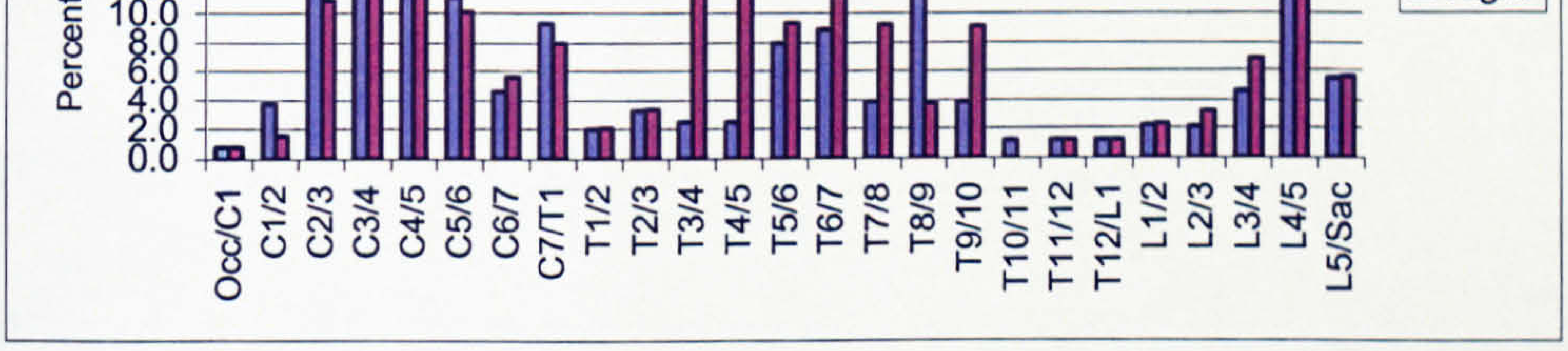


Fig. 5.4.11 Prevalence of vertebral osteoarthritis for German males by side affected (Occ=occipital condyles, C=cervical vertebra, T=thoracic vertebra, L=lumbar vertebra, Sac=sacral facets).

German males showed a higher prevalence of osteoarthritis on the left facets of their cervical vertebrae (CC1/2-C6/7) and on the right side of most thoracic vertebrae (T4/5-T7/8 and T9/10). For lower thoracic and upper lumbar vertebrae, prevalence was low on both body sides, but slightly more right facet joints were affected at the mid-lower lumbar level (L2/3-L3/4) (Fig. 5.4.11).

5.4.3 Degenerative disk disease (DDD)

Detailed information on degenerative disk disease (DDD) is listed on CD-ROM, Appendix C4 'Spinal DDD'. Table 5.4.45 provides information on the prevalence of degenerative disk disease (DDD) for individual sites by individuals affected, as well as for pooled samples. As for vertebral osteoarthritis, prevalence is given for specific spinal regions to accommodate differential preservation of the vertebral column. For pooled British sites, frequencies of DDD were highest in the cervical spine (21.56 percent), followed by the lumbar (18.62 percent) and thoracic spine (16.49 percent). However, for British samples, no statistically significant difference in prevalence of DDD was noticed between spinal regions (χ^2=1.5127, p=0.4694, d.f.=2). For pooled German sites, similar results were observed. Cervical spines had the highest prevalence (24.0 percent), followed by lumbar and thoracic spines (18.13 percent and 13.48 percent). For pooled German samples, differences between spinal regions were statistically significant, with the cervical region affected the most (χ^2=6.8997, p=0.0318, d.f.=2). Nevertheless, when comparing prevalence rates between the two countries, chi-squared tests did not confirm any statistical significance (cervical spine: χ^2=0.3078, p=0.5790, d.f.=1; thoracic spine: χ^2=0.6584, p=0.4171, d.f.=1; lumbar spine: χ^2=0.0142, p=0.9050, d.f.=1).

Site	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
Apple Down	19	74	25.68	12	71	16.9	13	69	19.12
Castledyke South	15	63	23.81	15	85	17.65	19	82	23.17
Norton	2	30	6.67	5	38	13.16	3	37	8.11
Total GB	36	167	21.56	32	194	16.49	35	188	18.62
Neresheim	16	76	21.05	6	76	7.89	8	67	11.94
Nusplingen	13	51	25.49	3	28	10.71	8	32	25.0
Pleidelsheim	19	73	26.03	15	74	20.27	15	72	20.83
Total D	48	200	24.0	24	178	13.48	31	171	18.13

Table 5.4.45 Prevalence of degenerative disk disease for specific spinal regions by individual sites (n=number of individuals affected, N=number of individuals preserved).

Table 5.4.46 demonstrates differences in prevalence rates between the sexes and a visual presentation of these results for females and males can be found in Fig. 5.4.12. For all spinal sections, British females had less DDD than British males and these differences were statistically significant for the cervical spine, but not for the thoracic and lumbar spine (cervical vertebrae: χ^2=5.1787, p=0.0229, d.f.=1; thoracic vertebrae: χ^2=0.9413, p=0.3320, d.f.=1; lumbar vertebrae: χ^2=0.6865, p=0.4074, d.f.=1). Similarly, German females had a lower prevalence of degenerative disk disease at all spinal regions compared to German males. Corresponding to British samples, these differences were only statistically significant in the cervical area (cervical vertebrae: χ^2=7.4911, p=0.0062, d.f.=1; thoracic vertebrae: χ^2=2.9351, p=0.0867, d.f.=1; lumbar vertebrae: χ^2=2.0975, p=0.1475, d.f.=1). Furthermore, no statistically significant differences were found when comparing prevalence rates between females and males between the two pooled samples (British and German females: (cervical vertebrae: χ^2=0.0944, p=0.7586, d.f.=1; thoracic vertebrae: χ^2=1.3297, p=0.2489, d.f.=1; lumbar vertebrae: χ^2=0.3426, p=0.5583, d.f.=1; British and German males: cervical vertebrae: χ^2=0.2010, p=0.6539, d.f.=1; thoracic vertebrae: χ^2=1.9363, p=0.1641, d.f.=1; lumbar vertebrae: χ^2=0.0081, p=0.9285, d.f.=1).

	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
GB Females	14	92	15.22	16	105	15.24	18	102	17.65
GB Males	20	66	30.3	16	77	20.78	17	75	22.67
GB N/D	2	9	22.2	0	12	0.0	0	11	0.0
Total GB	36	167	21.56	32	194	16.49	35	188	18.62
D Females	18	107	16.8	10	101	9.9	14	96	14.58
D Males	30	89	33.71	14	74	18.92	17	73	23.29
D N/D	0	4	0.0	0	3	0.0	0	2	0.0
Total D	48	200	24.0	24	178	13.48	31	171	18.13

Table 5.4.46 Prevalence of degenerative disk disease for specific spinal regions by sex (n=number of individuals affected, N=number of individuals preserved, GB=British samples, D=German samples, N/D=adults of undetermined sex).

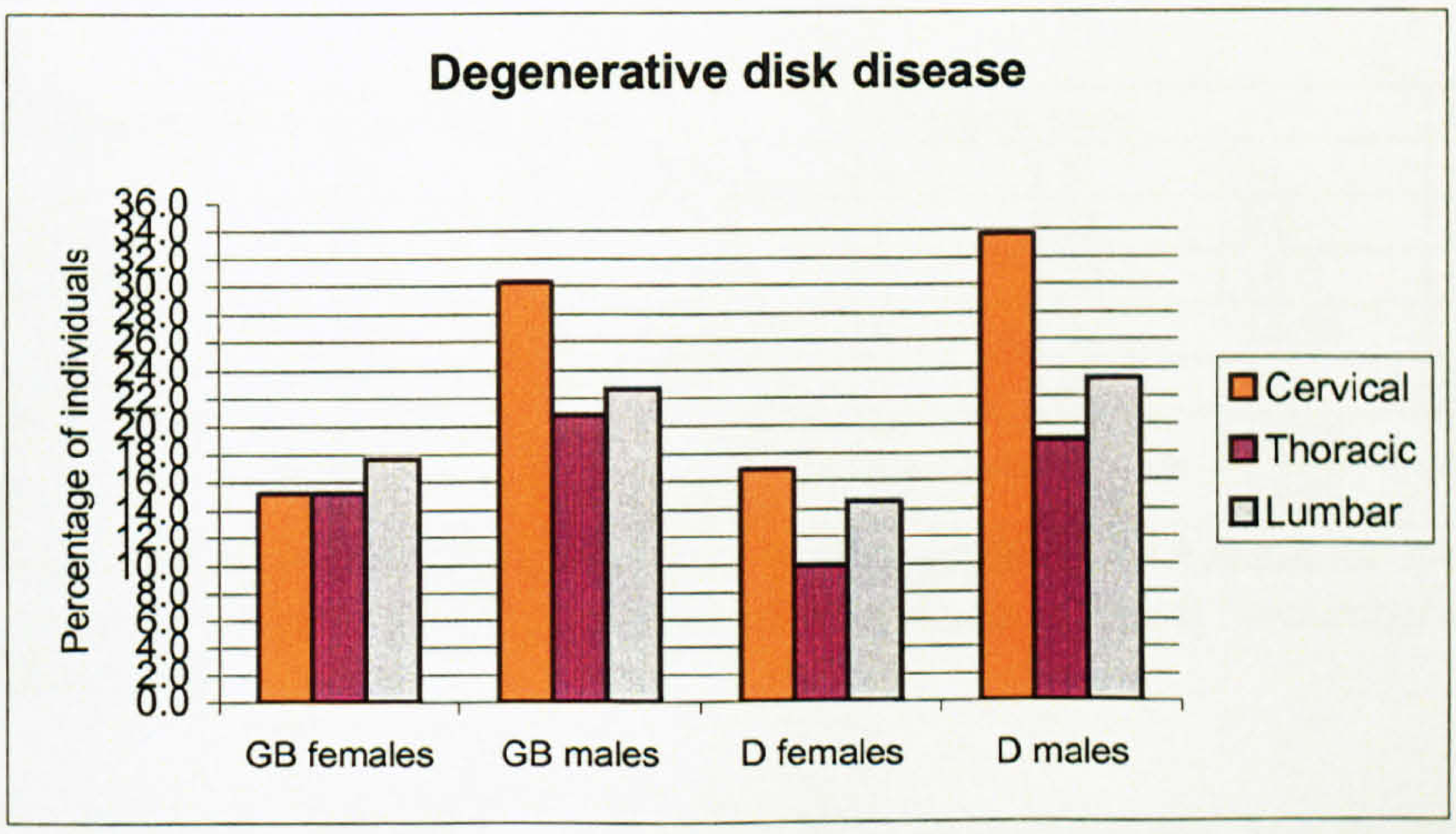


Fig. 5.4.12 Prevalence of females and males with degenerative disk disease for pooled samples by individuals affected (GB=pooled British samples, D=pooled German samples).

Prevalence of degenerative disk disease by age category for pooled British samples can be seen in Table 5.4.47 and results are also presented in Fig. 5.4.13. All spinal regions showed increasing frequencies with increasing age. No individual in the young adult age category and only a few in the next oldest category were affected, followed by a sharp increase in prevalence for middle-aged adults. More than half of all old adult individuals had DDD, especially in the thoracic spine.

British samples	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
16-25	0	30	0.0	0	35	0.0	0	36	0.0
26-35	3	49	6.12	4	64	6.25	6	61	9.84
36-45	17	54	31.48	16	60	26.67	18	56	32.14
45+	11	22	50.0	11	20	55.0	11	21	52.38
Adult	5	12	41.67	1	15	6.67	0	14	0.0
Total GB	36	167	21.56	32	194	16.49	35	188	18.62

Table 5.4.47 Age-related prevalence of degenerative disk disease for specific spinal regions of pooled British samples (n=number of individuals affected, N=number of individuals preserved).

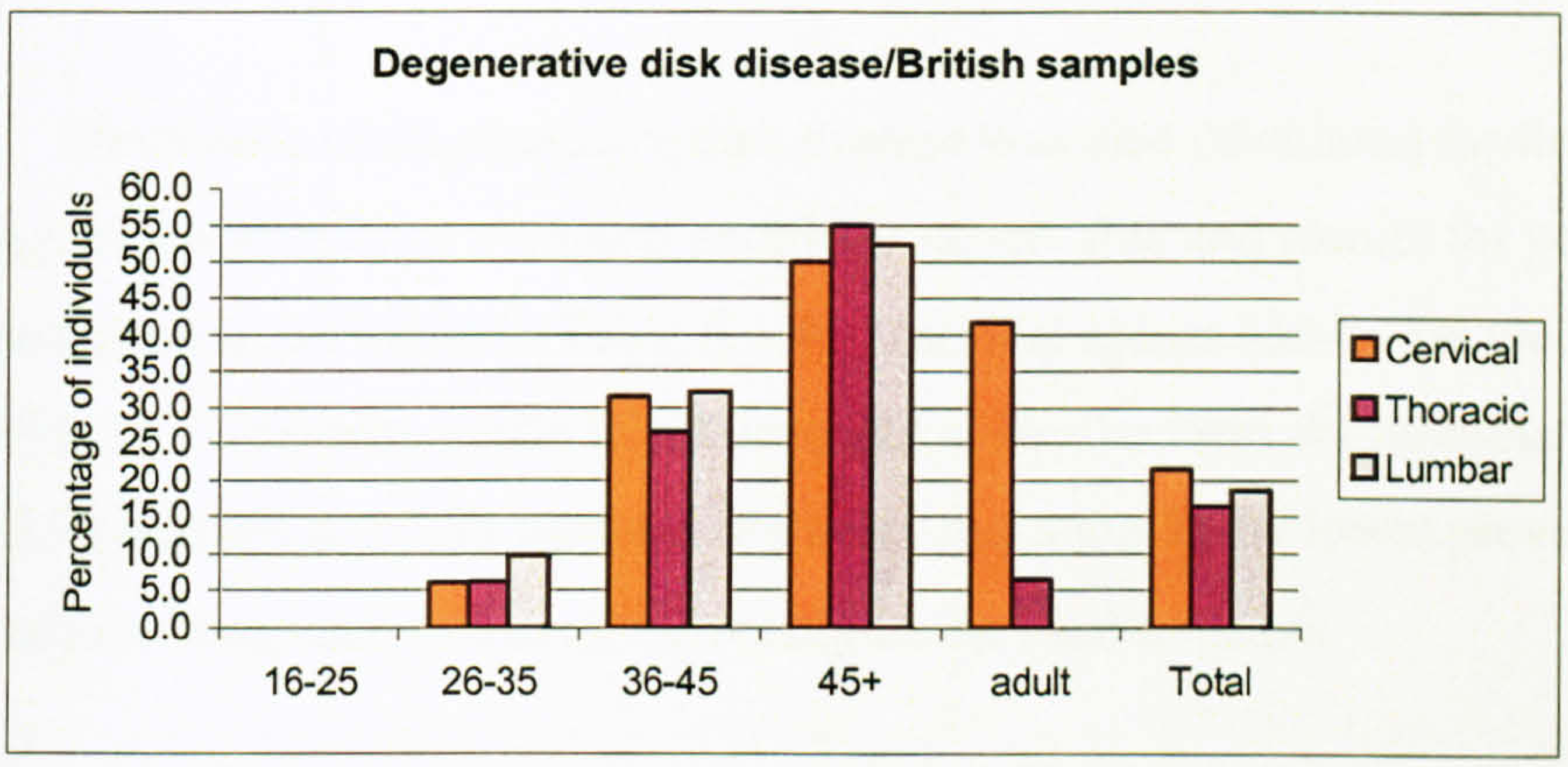


Fig. 5.4.13 Age-related prevalence of degenerative disk disease for pooled British samples by individuals affected.

German samples	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
16-25	0	24	0.0	0	23	0.0	3	24	12.5
26-35	7	76	9.21	7	70	10.0	5	65	7.69
36-45	21	59	35.59	8	49	16.33	12	53	22.64
45+	18	33	54.55	7	25	28.0	9	22	40.91
Adult	2	8	25.0	2	11	18.18	2	7	28.57
Total D	48	200	24.0	24	178	13.48	31	171	18.13

Table 5.4.48 Age-related prevalence of degenerative disk disease for specific spinal regions of pooled German samples (n=number of individuals affected, N=number of individuals preserved).

The same increase in prevalence with advancing age was observed for German samples and the results can be viewed in Table 5.4.48 and Fig. 5.4.14. With one exception, all spinal regions showed a steady increase in prevalence with increasing age.

Young adults had a higher prevalence of lumbar degenerative disk disease compared to young-middle aged adults. Nevertheless, the number of involved individuals in both age categories was low and results might have become distorted by this.

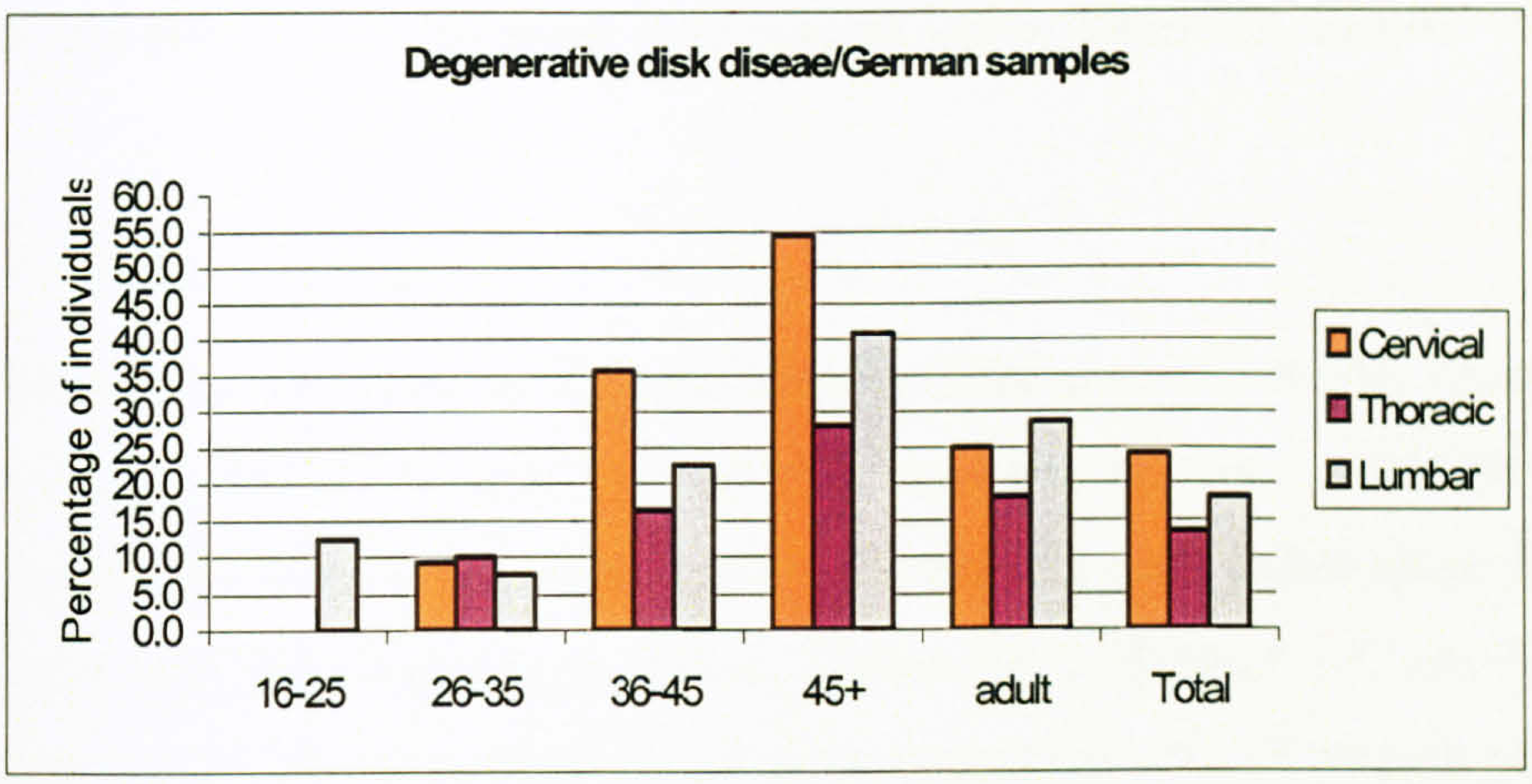


Fig. 5.4.14 Age-related prevalence of degenerative disk disease for pooled German samples by individuals affected.

Prevalence of degenerative disk disease was also calculated for the number of superior and inferior vertebral endplates observable and results for pooled British samples can be found in Table 5.4.49. Cervical spines had by far the highest prevalence with 11.11 percent, while DDD occurred at similar rates for thoracic and lumbar spines (5.93 percent and 5.83 percent). Females had a markedly lower prevalence in all spinal regions compared to males, especially in the lumbar spine.

	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
Females	52	653	7.96	61	1602	3.81	17	739	2.34
Males	87	568	15.32	110	1250	8.8	60	549	10.93
N/D	2	48	4.17	3	83	3.61	0	34	0.0
GB total	141	1269	11.11	174	2935	5.93	77	1322	5.83

Table 5.4.49 Prevalence of degenerative disk disease for pooled British samples by affected vertebral endplates (n=number of endplates affected, N=number of endplates preserved, N/D=adults of undetermined sex).

	Cervical spine			Thoracic spine			Lumbar spine		
	n	N	%	n	N	%	n	N	%
Females	42	658	6.38	19	1265	1.5	23	594	3.87
Males	129	581	22.2	76	1013	7.5	39	464	8.41
N/D	0	9	0.0	0	13	0.0	0	12	0.0
Total D	171	1248	13.7	95	2291	4.15	62	1070	5.79

Table 5.4.50 Prevalence of degenerative disk disease for pooled German samples by affected vertebral endplates (n=number of endplates affected, N=number of endplates preserved, N/D=adults of undetermined sex).

Prevalence of degenerative disk disease for pooled German samples by observable superior and inferior vertebral endplates can be seen in Table 5.4.50. Again, cervical spines displayed the highest prevalence within the vertebral column, with 13.7 percent of vertebral endplates affected. Prevalence for thoracic and lumbar vertebral endplates was less than half of this value, 4.15 percent and 5.79 percent, respectively.

5.4.4 Schmorl's nodes

Detailed information on Schmorl's nodes is listed on CD-ROM, Appendix C4 'Schmorl's Nodes'. Schmorl's nodes were not found on any cervical vertebrae and therefore results were only presented for the thoracic and lumbar spine. Prevalence for individual sites by individuals affected can be seen in Table 5.4.51. At Apple Down and Castledyke South, more than half of all thoracic spines (52.86 percent and 52.94 percent) were affected and they had a higher prevalence of Schmorl's nodes than lumbar spines (42.65 percent and 31.71 percent). The contrary was observed at Norton (13.16 percent and 16.22 percent). However, for pooled samples, thoracic spines were more prone to display Schmorl's nodes on a statistically significant level (χ^2=6.1985, p=0.0128, d.f.=1). Among German samples, prevalence between thoracic and lumbar spines was more evenly distributed, at least at Neresheim (39.47percent and 37.31 percent) and Nusplingen (28.57 percent and 28.13 percent). At Pleidelsheim, a markedly higher frequency of Schmorl's nodes was present on the thoracic spine compared to the lumbar spine (43.24 percent and 31.94 percent). For pooled German samples, no statistically significant difference was found between the two spinal regions (χ^2=1.3530, p=0.2448, d.f.=1). Overall prevalence between British and German samples did not differ significantly (thoracic spine: χ^2=1.2550, p=0.2626, d.f.=1; lumbar spine: χ^2=0.0206, p=0.8860, d.f.=1).

Site	Thoracic spine			Lumbar spine		
	n	N	%	n	N	%
Apple Down	37	70	52.86	29	68	42.65
Castledyke South	45	85	52.94	26	82	31.71
Norton	5	38	13.16	6	37	16.22
Total GB	87	193	45.08	61	187	32.62
Neresheim	30	76	39.47	25	67	37.31
Nusplingen	8	28	28.57	9	32	28.13
Pleidelsheim	32	74	43.24	23	72	31.94
Total D	70	178	39.33	57	171	33.33

Table 5.4.51 Prevalence of Schmorl's nodes for specific spinal regions by individual sites (n=number of individuals affected, N=number of individuals preserved, Total GB=pooled British samples, Total D=pooled German samples).

Table 5.4.52 lists results for Schmorl's nodes prevalence for individuals by sex, including adults of undetermined sex and Fig. 5.4.15 does the same for females and males alone. British males displayed higher rates than British females, but the difference was not statistically significant, neither for thoracic nor lumbar spines (thoracic spine: χ^2=0.6178, p=0.4319, d.f.=1; lumbar spine: χ^2=0.4747, p=0.4909, d.f.=1). A similar observation was made for German females and males; more males had Schmorl's nodes in both spinal regions, and here the differences were statistically significant (thoracic spine: χ^2=9.4596, p=0.0021, d.f.=1; lumbar spine: χ^2=8.4492, p=0.0037, d.f.=1). Comparisons between the sexes across the countries revealed only one statistically significant result: German females had significantly fewer Schmorl's nodes in their thoracic spines than British females (χ^2=4.9875, p=0.0255, d.f.=1). Insignificant differences were found for British and German female lumbar spines (χ^2=1.7181, p=0.1899, d.f.=1) and male thoracic and lumbar spines (χ^2=0.0637, p=0.8007, d.f.=1 and χ^2=0.9462, p=0.3307, d.f.=1).

	Thoracic spine			Lumbar spine		
GB samples	n	N	%	n	N	%
Females	47	105	44.76	33	102	32.35
Males	39	77	50.65	28	75	37.33
N/D	1	11	9.09	0	10	0.0
Total GB	87	193	45.08	61	187	32.62
D samples	n	N	%	n	N	%
Females	30	101	29.7	23	96	23.96
Males	39	74	52.7	33	73	45.21
N/D	1	3	33.33	1	2	50.0
Total D	70	178	39.33	57	171	33.33

Table 5.4.52 Prevalence of Schmorl's nodes for specific spinal regions by sex (n=number of individuals affected, N=number of individuals preserved, N/D=adults of undetermined sex, GB=pooled British samples, D=pooled German samples).

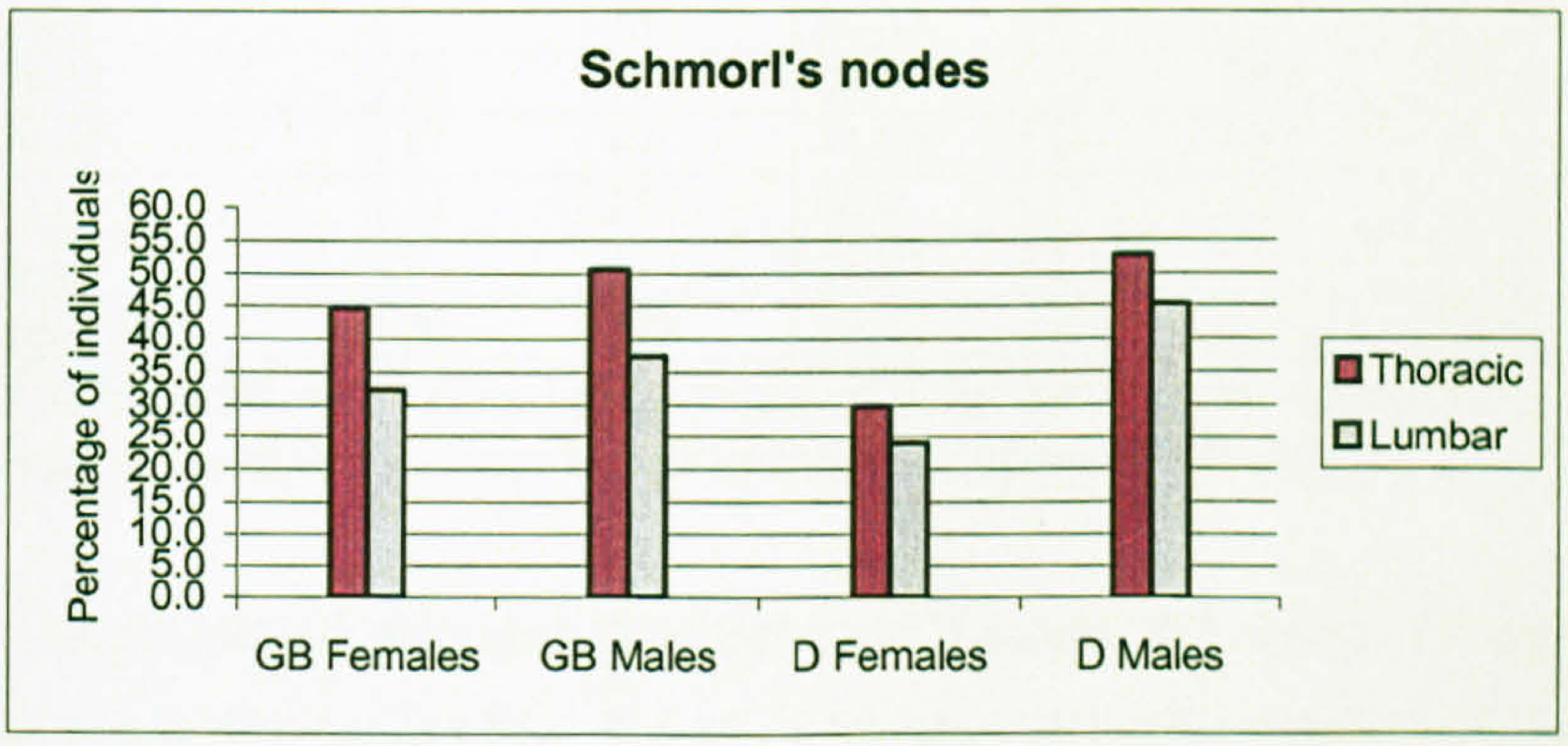


Fig. 5.4.15 Prevalence of females and males with Schmorl's nodes for pooled samples by individuals affected (GB=pooled British samples, D=pooled German samples).

Prevalence of Schmorl's nodes for pooled British samples by individuals affected in each adult age group can be found in Table 5.4.53 and Fig. 5.4.16. Although there was a slight increase in prevalence with advancing age in both spinal regions, a large proportion of young adults had experienced Schmorl's nodes, especially in the thoracic spine.

British samples	Thoracic spine			Lumbar spine		
	n	N	%	n	N	%
16-25	13	35	37.14	6	36	16.67
26-35	29	64	45.31	17	61	27.87
36-45	33	60	55.0	26	56	46.43
45+	10	20	50.0	11	21	52.38
Adult	2	14	14.29	1	13	7.69
Total GB	87	193	45.08	61	187	32.62

Table 5.4.53 Age-related prevalence of degenerative disk disease for specific spinal regions of pooled British samples (n=number of individuals affected, N=number of individuals preserved).

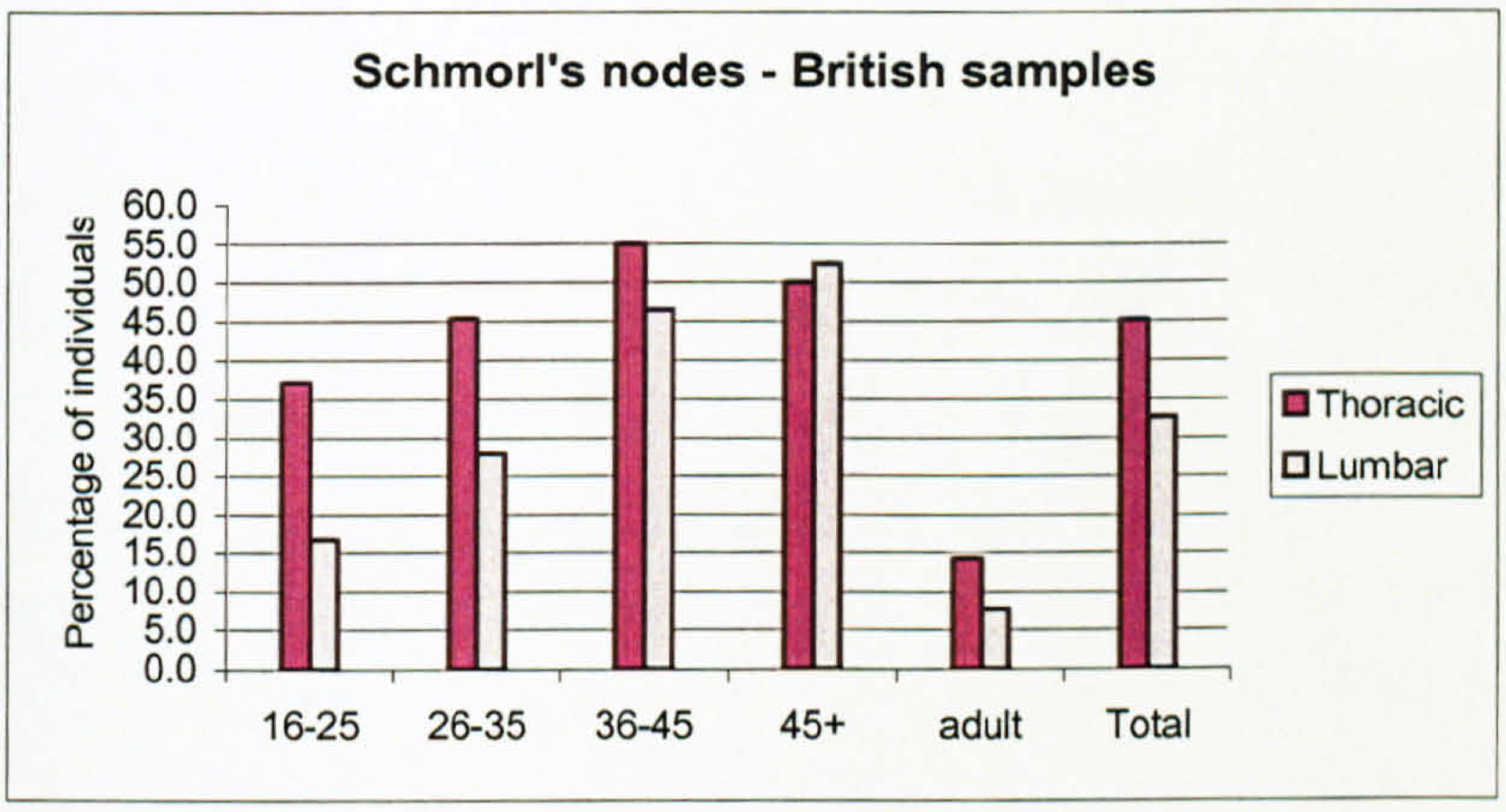


Fig. 5.4.16 Age-related prevalence of Schmorl's nodes for pooled British samples by individuals affected.

German samples	Thoracic spine			Lumbar spine		
	n	N	%	n	N	%
16-25	7	23	30.43	8	24	33.33
26-35	28	70	40.0	19	65	29.23
36-45	17	49	34.69	15	53	28.3
45+	15	25	60.0	13	22	59.09
Adult	3	11	27.27	2	7	28.57
Total D	70	178	39.33	57	171	33.33

Table 5.4.54 Age-related prevalence of Schmorl's nodes for specific spinal regions of pooled German samples (n=number of individuals affected, N=number of individuals preserved).

Age-related prevalence of Schmorl's nodes for pooled German samples can be seen in Table 5.4.54 and Fig. 5.4.17. Although old adults had the highest prevalence rates for Schmorl's nodes of the thoracic and lumbar spine, young adults were slightly more often affected than middle-aged adults, thus distorting a constant increase in prevalence with advancing age.

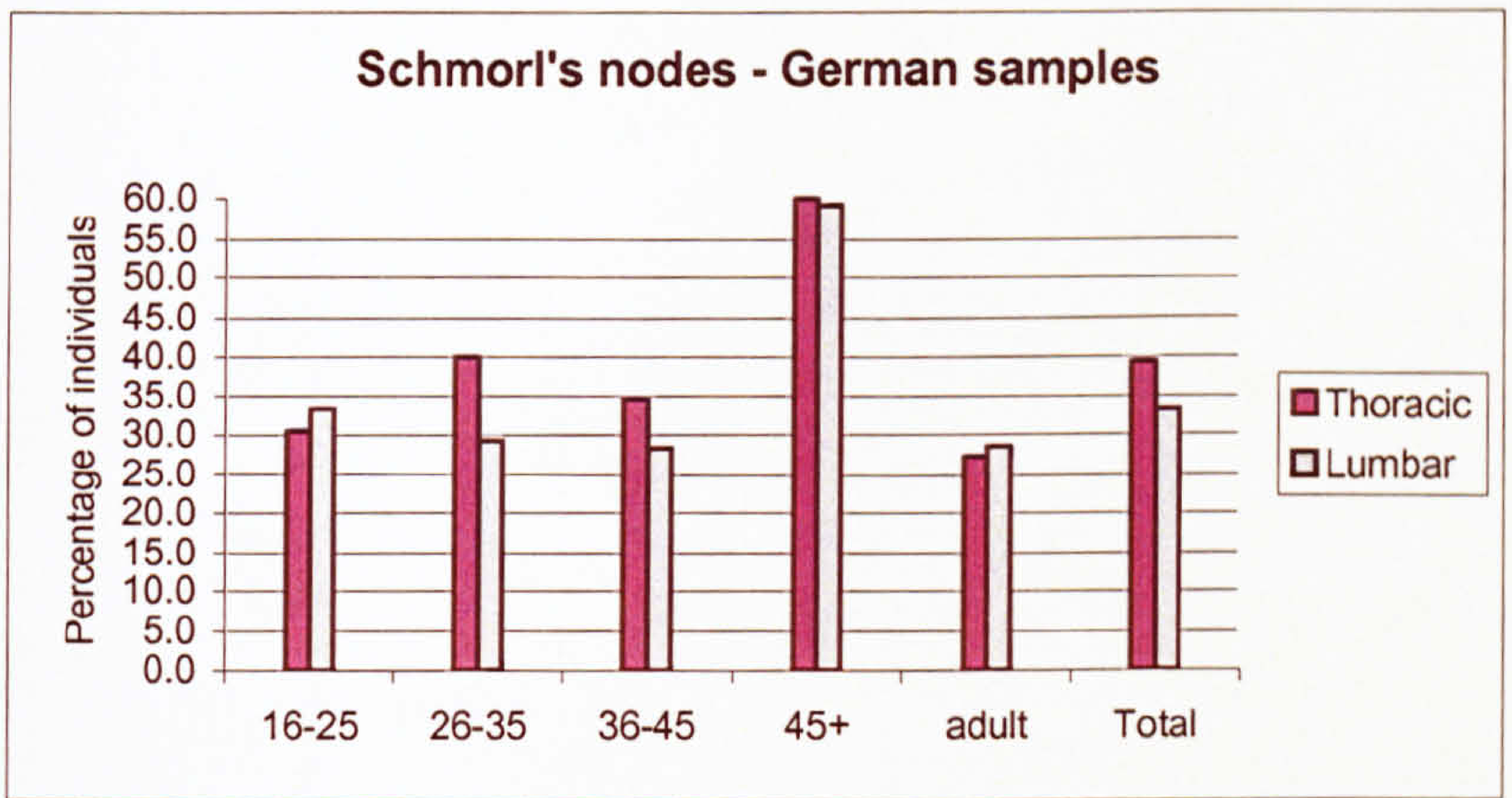


Fig. 5.4.17 Age-related prevalence of Schmorl's nodes for pooled German samples by individuals affected.

Table 5.4.55 gives details on Schmorl's nodes prevalence for the number of vertebral endplates affected from pooled British samples. As for individuals affected, thoracic spines had a higher frequency of Schmorl's nodes than lumbar spines (17.68 percent and 14.87 percent). British females had a lower prevalence for both spinal regions compared to British males; 15.79 percent of female thoracic endplates and 21.14 percent of male thoracic endplates were affected. Similarly, British females had 13.83 percent of lumbar endplates displaying Schmorl's nodes and British males showed a frequency of 17.18 percent.

	Thoracic spine			Lumbar spine		
	n	N	%	n	N	%
Females	253	1602	15.79	103	745	13.83
Males	266	1258	21.14	95	553	17.18
N/D	1	82	1.22	0	34	0.0
Total GB	520	2942	17.68	198	1332	14.87

Table 5.4.55 Prevalence of Schmorl's nodes for pooled British samples by affected vertebral endplates (n=number of endplates affected, N=number of endplates preserved, N/D=adults of undetermined sex).

Finally, prevalence for Schmorl's nodes for pooled German samples by number of affected vertebral endplates is tabulated in Table 5.4.56. The difference between thoracic and lumbar prevalence is minimal, with 13.29 percent and 12.97 percent affected, respectively, in pooled German samples. German females had slightly more Schmorl's nodes on their lumbar endplates (10.85 percent), than on their thoracic endplates (9.89 percent). In contrast, German males had 17.19 percent of their thoracic endplates showing Schmorl's nodes and 14.89 percent of lumbar endplates affected.

	Thoracic spine			Lumbar spine		
	n	N	%	n	N	%
Females	125	1264	9.89	64	590	10.85
Males	176	1024	17.19	70	470	14.89
N/D	5	14	35.71	5	12	41.67
Total D	306	2302	13.29	139	1072	12.97

Table 5.4.56 Prevalence of Schmorl's nodes for pooled German samples by affected vertebral endplates (n=number of endplates affected, N=number of endplates preserved, N/D=adults of undetermined sex).

5.5 Trauma

5.5.1 Postcranial fractures

All individuals with long bone fractures are listed in Appendix C5, Table 1, while information on non-long bone fractures is provided in Appendix C5, Table 2.

Clavicle fractures

Prevalence for fractures of the clavicle by individuals affected can be found in Tables 5.5.1 (British samples) and 5.5.2 (German samples). Among British sites, the highest frequency was seen at Castledyke South; here, 13.56 percent of individuals had fractured their clavicle. At Apple Down, far fewer individuals had sustained a fracture of this skeletal element – 7.02 percent were affected and at Norton, only 3.57 percent were found. A total of 8.13 percent of all individuals with both clavicles present were affected.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	31	0.0	0	24	0.0	1	18	5.56	1	73	1.37
Males	4	26	15.39	5	14	35.71	0	8	0.0	9	48	18.75
N/D	0	0	0.0	0	0	0.0	0	2	0.0	0	2	0.0
Total	4	57	7.02	5	38	13.56	1	28	3.57	10	123	8.13

Table 5.5.1 Prevalence of clavicle fractures by individuals affected for individual sites and pooled British samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

A similar distribution was found for German samples. At Nusplingen, 9.09 percent, at Pleidelsheim, 6.67 percent and at Neresheim, 4.65 percent had sustained a fractured clavicle. One male individual from Neresheim (NE80) had both clavicles affected. An overall prevalence of 6.14 percent was seen in pooled German samples. Although British prevalence for clavicle fractures was higher than for German sites, this difference was statistically not significant (χ^2=0.3518, p=0.5531, d.f.=1). Females in both pooled samples had markedly lower frequencies than their male contemporaries: only one British female was affected (1.37 percent), while nine British males had sustained a fractured clavicle (18.75 percent). Fractured clavicles were found in two German females (3.45 percent) as opposed to five German males (9.09 percent).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
·	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	25	0.0	1	6	16.67	1	27	3.7	2	58	3.45
Males	2	18	11.11	0	5	0.0	3	32	9.38	5	55	9.09
N/D	0	0	0.0	0	0	0.0	0	1	0.0	0	1	0.0
Total	2	43	4.65	1	11	9.09	4	60	6.67	7	114	6.14

Table 5.5.2 Prevalence of clavicle fractures by individuals affected for individual sites and pooled German samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

Additionally, prevalence for clavicle fractures was calculated by bones preserved and results are presented in Tables 5.5.3 (British samples) and 5.5.4 (German samples). Again, Castledyke South showed the highest prevalence for all three British sites (5.26 percent), followed by Apple Down (3.13 percent) and Norton (1.47 percent). The overall prevalence of 3.44 percent for British samples was slightly higher than the frequency of 2.99 percent observed for German samples. Among German sites, frequencies were less varied, and ranged between 2.78 percent at Neresheim, 3.03 percent at Pleidelsheim and 3.57 percent at Nusplingen. The same male predominance was found with regard to the number of clavicles affected. British females had a low frequency with 0.57 percent, but in contrast 8.26 percent of all clavicles attributed to males were fractured. Similarly, German females had fewer clavicle fractures than German males, 1.41 percent and 4.92 percent, respectively.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	72	0.0	0	63	0.0	1	40	2.5	1	175	0.57
Males	4	56	7.14	5	32	15.63	0	21	0.0	9	109	8.26
N/D	0	0	0.0	0	0	0.0	0	7	0.0	0	7	0.0
Total	4	128	3.13	5	95	5.26	1	68	1.47	10	291	3.44

Table 5.5.3 Prevalence of clavicle fractures by clavicles affected for individual sites and pooled British samples (n=number of clavicles affected, N=number of clavicles observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	N	N	%	n	N	%	n	N	%
Females	0	66	0.0	1	14	7.14	1	62	1.61	2	142	1.41
Males	3	42	7.14	0	13	0.0	3	67	4.48	6	122	4.92
N/D	0	0	0.0	0	1	0.0	0	3	0.0	0	4	0.0
Total	3	108	2.78	1	28	3.57	4	132	3.03	8	268	2.99

Table 5.5.4 Prevalence of clavicle fractures by clavicles affected for individual sites and pooled German samples (n=number of clavicles affected, N=number of clavicles observable, N/D=adults of undetermined sex).

Humerus fractures

Only one example of a fractured humerus was present in the study samples and therefore no detailed prevalence tables were provided. An old adult male from Nusplingen (NU47) had a healed fracture of the right proximal diaphysis of the humerus, displaying secondary osteoarthritis of the humerus head and localized inflammation in the form of woven new bone formation distally to the fracture site. The prevalence for humerus fractures for male individuals from Nusplingen was 6.25 percent with regard to individuals affected (1 of 16 males) and 2.08 percent for humeri (1 of 48 male humeri). Overall prevalence for pooled German samples was 0.27 percent by skeletal element (1 of 376 humeri). However, none of 308 humeri from the pooled British samples was fractured.

Radius fractures

Results for radius fractures by affected individuals can be seen in Tables 5.5.5 (British samples) and 5.5.6 (German samples). There was a noticeable disparity in radius fractures between the two countries. One female from Castledyke South was affected, resulting in a low prevalence of 0.85 percent for British samples. In contrast, seven fractured radii were found in the pooled German samples (7.69 percent), resulting in a nine-fold higher prevalence compared to British sites. German males were particularly affected; one-quarter of male individuals from Neresheim and Nusplingen, as well as 4.55 percent of men from Pleidelsheim were involved. Only one female from Neresheim had fractured her radius (6.67 percent).

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	26	0.0	1	18	5.56	0	16	0.0	1	60	1.67
Males	0	25	0.0	0	17	0.0	0	12	0.0	0	54	0.0
N/D	0	1	0.0	0	2	0.0	0	1	0.0	0	4	0.0
Total	0	52	0.0	1	37	2.7	0	29	0.0	1	118	0.85

Table 5.5.5 Prevalence of individuals with radius fractures by individuals affected for individual sites and pooled British samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	1	15	6.67	0	11	0.0	0	22	0.0	1	48	2.08
Males	4	16	25.0	1	4	25.0	1	22	4.55	6	42	14.29
N/D	0	0	0.0	0	1	0.0	0	0	0.0	0	1	0.0
Total	5	31	16.13	1	16	6.25	1	44	2.27	7	91	7.69

Table 5.5.6 Prevalence of individuals with radius fractures by individuals affected for individual sites and pooled German samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

Prevalence for radius fractures by bones affected is detailed in Tables 5.5.7 (British samples) and 5.5.8 (German samples). With only one fractured radius, frequency among British samples was low; 0.35 percent were affected. Seven of 260 German radii showed evidence of fracture, resulting in a prevalence of 2.69 percent. German males had a comparatively high number of radius fractures, with 6 of 117 male radii (5.13 percent) affected, but only 0.73 percent of female radii from German sites and 0.63 percent of British female radii were involved.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	64	0.0	1	55	1.82	0	40	0.0	1	159	0.63
Males	0	52	0.0	0	44	0.0	0	26	0.0	0	122	0.0
N/D	0	2	0.0	0	4	0.0	0	3	0.0	0	5	0.0
Total	0	118	0.0	1	103	0.97	0	45	0.0	1	286	0.35

Table 5.5.7 Prevalence of radius fractures by radii affected for individual sites and pooled British samples (n=number of radii affected, N=number of radii observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	N	N	%	n	N	%	n	N	%
Females	1	47	2.13	0	34	0.0	0	56	0.0	1	137	0.73
Males	4	44	9.09	1	21	4.76	1	52	1.92	6	117	5.13
N/D	0	1	0.0	0	2	0.0	0	3	0.0	0	6	0.0
Total	5	92	5.43	1	57	1.75	1	111	0.9	7	260	2.69

Table 5.5.8 Prevalence of radius fractures by ribs affected for individual sites and pooled German samples (n=number of radii affected, N=number of radii observable, N/D=adults of undetermined sex).

Ulna fractures

Tables 5.5.9 (British samples) and 5.5.10 (German samples) list prevalence of ulna fractures by individuals affected. One male from Castledyke South was the sole example of an ulna fracture among British sites, resulting in an overall prevalence of 0.94 percent (1 of 106 individuals). Frequency rates for German sites were higher; here 3.85 percent of individuals were affected. In both countries, only men had experienced fractures of their ulnae; 1.96 of British males and 8.11 percent of German males were involved.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	26	0.0	0	13	0.0	0	15	0.0	0	54	0.0
Males	0	24	0.0	1	17	5.88	0	10	0.0	1	51	1.96
N/D	0	1	0.0	0	0	0.0	0	0	0.0	0	1	0.0
Total	0	51	0.0	1	30	3.33	0	25	0.0	1	106	0.94

Table 5.5.9 Prevalence of ulna fractures by individuals affected for individual sites and pooled British samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	14	0.0	0	7	0.0	0	18	0.0	0	39	0.0
Males	0	9	0.0	1	7	14.29	2	21	9.52	3	37	8.11
N/D	0	0	0.0	0	2	0.0	0	0	0.0	0	2	0.0
Total	0	23	0.0	1	16	6.25	2	39	5.13	3	78	3.85

Table 5.5.10 Prevalence of ulna fractures by individuals affected for individual sites and pooled German samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

In Tables 5.5.11 (British samples) and 5.5.12 (German samples), prevalence of ulna fractures is detailed by bones affected. A total of 0.36 percent of all British ulnae was fractured, as opposed to 1.26 percent of German ulnae. Ulna fractures occurred in 0.79 percent of British male ulnae and 2.8 percent of German male ulnae, but not in any of the preserved female ulnae.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	64	0.0	0	43	0.0	0	40	0.0	0	147	0.0
Males	0	54	0.0	1	47	2.13	0	25	0.0	1	126	0.79
N/D	0	2	0.0	0	3	0.0	0	4	0.0	0	9	0.0
Total	0	120	0.0	1	93	1.08	0	69	0.0	1	282	0.36

Table 5.5.11 Prevalence of ulna fractures by ulnae affected for individual sites and pooled British samples (n=number of ulnae affected, N=number of ulnae observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	N	N	%	n	N	%	n	N	%
Females	0	46	0.0	0	29	0.0	0	50	0.0	0	125	0.0
Males	0	35	0.0	1	27	3.7	2	45	4.44	3	107	2.8
N/D	0	0	0.0	0	4	0.0	0	3	0.0	0	7	0.0
Total	0	81	0.0	1	60	1.67	2	98	2.04	3	239	1.26

Table 5.5.12 Prevalence of ulna fractures by ulnae affected for individual sites and pooled German samples (n=number of ulnae affected, N=number of ulnae observable, N/D=adults of undetermined sex).

Femur fractures

Prevalence of femur fractures by affected individuals is given in Tables 5.5.13 (British samples) and 5.5.14 (German samples). In both pooled samples, only two individuals had experienced fractures of this bone. Frequencies were similar, with 1.37 percent affected among British samples and 1.17 percent of German individuals. No females were involved in the British samples, but male prevalence was 3.39 percent. In contrast, one female and one male had sustained a femur fracture in the German samples. This resulted in a female prevalence of 1.05 percent and a male prevalence of 1.43 percent.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	30	0.0	0	33	0.0	0	19	0.0	0	82	0.0
Males	1	25	4.0	0	24	0.0	1	10	10.0	2	59	3.39
N/D	0	2	0.0	0	3	0.0	0	0	0.0	0	5	0.0
Total	1	57	1.75	0	60	0.0	1	29	3.45	2	146	1.37

Table 5.5.13 Prevalence of femur fractures by individuals affected for individual sites and pooled British samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	36	0.0	1	21	4.76	0	38	0.0	1	95	1.05
Males	0	24	0.0	0	15	0.0	1	31	3.23	1	70	1.43
N/D	0	1	0.0	0	2	0.0	0	3	0.0	0	6	0.0
Total	0	61	0.0	1	38	2.63	1	72	1.39	2	171	1.17

Table 5.5.14 Prevalence of femur fractures by individuals affected for individual sites and pooled German samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

The prevalence rates of femur fractures with regard to bones affected are tabulated in Tables 5.5.15 (British samples) and 5.5.16 (German samples). As for individuals, similar frequencies were found in both countries. Overall, 0.59 percent of British femora and 0.49 percent of German femora were fractured. However, male prevalence among British sites was higher than for German males; 1.52 percent of British male femora and 0.58 percent of German male femora were affected. In addition, 0.47 percent of female femora from German samples were fractured.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	69	0.0	0	75	0.0	0	49	0.0	0	193	0.0
Males	1	53	1.89	0	52	0.0	1	27	3.7	2	132	1.52
N/D	0	4	0.0	0	9	0.0	0	3	0.0	0	16	0.0
Total	1	126	0.79	0	136	0.0	1	79	1.27	2	341	0.59

Table 5.5.15 Prevalence of femur fractures by femora affected for individual sites and pooled British samples (n=number of femora affected, N=number of femora observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	N	N	%	n	N	%	n	N	%
Females	0	81	0.0	1	52	1.92	0	82	0.0	1	215	0.47
Males	0	56	0.0	0	48	0.0	1	70	1.43	1	174	0.58
N/D	0	3	0.0	0	6	0.0	0	9	0.0	0	18	0.0
Total	0	140	0.0	1	106	0.94	1	161	0.62	2	407	0.49

Table 5.5.16 Prevalence of femur fractures by femora affected for individual sites and pooled German samples (n=number of femora affected, N=number of femora observable, N/D=adults of undetermined sex).

Tibia fractures

Prevalence of tibia fractures can be found in Tables 5.5.17 (British samples) and 5.5.18 (German samples). None of the 136 British individuals had sustained a fracture of the tibia, while nine of 139 German individuals were affected. The overall prevalence for German samples was 6.48 percent. German males had a higher frequency of fractured tibiae than German females; 11.11 percent of men and 2.78 percent of German females had experienced a fractured tibia.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	27	0.0	0	25	0.0	0	17	0.0	0	69	0.0
Males	0	24	0.0	0	26	0.0	0	9	0.0	0	59	0.0
N/D	0	4	0.0	0	4	0.0	0	0	0.0	0	8	0.0
Total	0	55	0.0	0	55	0.0	0	26	0.0	0	136	0.0

Table 5.5.17 Prevalence of tibia fractures by individuals affected for individual sites and pooled British samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	2	18	11.11	0	16	0.0	0	38	0.0	2	72	2.78
Males	2	13	15.39	3	17	17.65	2	33	6.06	7	63	11.11
N/D	0	0	0.0	0	2	0.0	0	2	0.0	0	4	0.0
Total	4	31	12.9	3	35	8.57	2	73	2.74	9	139	6.48

Table 5.5.18 Prevalence of tibia fractures by individuals affected for individual sites and pooled German samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

Prevalence for tibia fractures by bones affected is tabulated in Tables 5.5.19 (British samples) and 5.5.20 (German samples). None of 319 British tibiae was fractured, while 2.59 percent of German tibiae were involved. Female prevalence was comparatively low, with 1.08 percent affected. However, 4.7 percent of male tibiae were fractured.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	63	0.0	0	68	0.0	0	39	0.0	0	170	0.0
Males	0	51	0.0	0	58	0.0	0	21	0.0	0	130	0.0
N/D	0	2	0.0	0	15	0.0	0	2	0.0	0	19	0.0
Total	0	106	0.0	0	141	0.0	0	62	0.0	0	319	0.0

Table 5.5.19 Prevalence of tibia fractures by tibiae affected for individual sites and pooled British samples (n=number of tibiae affected, N=number of tibiae observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	N	N	%	n	N	%	n	N	%
Females	2	57	3.51	0	46	0.0	0	82	0.0	2	185	1.08
Males	2	39	5.13	3	45	6.67	2	65	3.08	7	149	4.7
N/D	0	1	0.0	0	7	0.0	0	5	0.0	0	13	0.0
Total	4	97	4.12	3	98	3.06	2	152	1.32	9	347	2.59

Table 5.5.20 Prevalence of tibia fractures by tibiae affected for individual sites and pooled German samples (n=number of tibiae affected, N=number of tibiae observable, N/D=adults of undetermined sex).

Fibula fractures

Tables 5.5.21 and 5.5.22 list the prevalence for fibula fractures by individuals affected for British and German samples, respectively. Four of 113 British individuals had sustained a fractured fibula, resulting in a prevalence of 3.54 percent. However, German individuals had a noticeable higher prevalence, with 12.31 percent of all individuals having sustained a fractured fibula. Only one British female (1.72 percent) and three British males (5.88 percent) were affected. A similar higher male prevalence was found for German individuals; 9.38 percent of females and 16.13 percent of males fractured their fibulae.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	27	0.0	1	17	5.88	0	14	0.0	1	58	1.72
Males	2	25	8.0	1	19	5.26	0	7	0.0	3	51	5.88
N/D	0	1	0.0	0	3	0.0	0	0	0.0	0	4	0.0
Total	2	53	3.77	2	43	4.65	0	21	0.0	4	113	3.54

Table 5.5.21 Prevalence of fibula fractures by individuals affected for individual sites and pooled British samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	3	18	16.67	0	1	0.0	0	13	0.0	3	32	9.38
Males	2	12	16.67	1	1	100.0	2	18	11.11	5	31	16.13
N/D	0	0	0.0	0	1	0.0	0	1	0.0	0	2	0.0
Total	5	30	16.67	1	3	33.33	2	32	6.25	8	65	12.31

Table 5.5.22 Prevalence of fibula fractures by individuals affected for individual sites and pooled German samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

The prevalence of fibula fractures by bones affected can be found in Tables 5.5.23 (British samples) and 5.5.24 (German samples). A total of 1.49 percent of all fibulae were fractured in the British samples. Among German sites, 4.3 percent of fibulae were involved. Males in both countries had a higher fracture prevalence than females. One female fibula from the British sites was fractured (0.71 percent), while 2.63 percent of male fibulae showed evidence of fracture. Three of 95 female fibulae from German sites (3.16 percent) and five of 86 male fibulae (5.81 percent) were fractured.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	57	0.0	1	49	2.04	0	34	0.0	1	140	0.71
Males	2	51	3.92	1	46	2.17	0	17	0.0	3	114	2.63
N/D	0	2	0.0	0	10	0.0	0	2	0.0	0	14	0.0
Total	2	110	1.82	2	105	1.91	0	53	0.0	4	268	1.49

Table 5.5.23 Prevalence of fibula fractures by fibulae affected for individual sites and pooled British samples (n=number of fibulae affected, N=number of fibulae observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	3	45	6.67	0	16	0.0	0	34	0.0	3	95	3.16
Males	2	28	7.14	1	14	7.14	2	44	4.55	5	86	5.81
N/D	0	1	0.0	0	2	0.0	0	2	0.0	0	5	0.0
Total	5	74	6.76	1	32	3.13	2	80	2.5	8	186	4.3

Table 5.5.24 Prevalence of fibula fractures by fibulae affected for individual sites and pooled German samples (n=number of fibulae affected, N=number of fibulae observable, N/D=adults of undetermined sex).

Table 5.5.25 provides information on the overall prevalence of long bone fractures by individuals affected. In both countries, females experienced fewer fractures; British females had a prevalence of 2.1 percent. However, German females had more than twice as many long bone fractures, at 4.27 percent. Due to the low number of British females affected, no chi-squared test could be employed to test for statistical significance. British and German male frequencies were noticeable higher; 14.14 percent of British males and 15.56 percent of German males had sustained one or more fractured long bones. The difference in male prevalence was statistically not significant (χ^2=0.0898, p=0.7644, d.f.=1). However, German females had significantly fewer long bone fractures than German males (χ^2=11.1143, p=0.0009, d.f.=1). Ultimately, no statistically significant difference was noted when overall prevalence rates were compared between the two pooled samples (χ^2=1.7450, p=0.1865, d.f.=1).

	British samples				German samples		
	n	N	%		n	N	%
Females	3	143	2.1	Females	7	164	4.27
Males	14	99	14.14	Males	21	135	15.56
N/D	0	46	0.0	N/D	0	35	0.0
Total	17	288	5.9	Total	28	334	8.38

Table 5.5.25 Prevalence of long bone fractures by individuals affected for pooled samples (N/D=adult of undetermined sex).

Overall prevalence of long bone fractures by bones affected is depicted in Table 5.5.26. A total of 18 out of 2,095 long bones were fractured in the British samples (0.86 percent); one male (CS93) had experienced a fractured clavicle and ulna. Among 2,083 long bones from German sites, 38 showed evidence of fracture (1.82 percent). Two females (NE5 and NE30) and six males (NE80, NE102, NU169, PL79, PL111 and PL113) had sustained more than one fractured long bone. Seven of them had two long bone fractures, while one male (NE80) had suffered four fractured bones. British males had a fracture prevalence of 1.74 percent (15 of 864 male long bones), while British females had a frequency of only 0.26 percent (3 of 1,163 female long bones). Equally, German females had a lower prevalence than German males; 0.82 percent (9 of 1,094 female long bones) as opposed to 3.15 percent (29 of 920 male long bones).

	British samples				German samples		
	n	N	%		n	N	%
Females	3	1163	0.26	Females	9	1094	0.82
Males	15	864	1.74	Males	29	920	3.15
N/D	0	68	0.0	N/D	0	69	0.0
Total	18	2095	0.86	Total	38	2083	1.82

Table 5.5.26 Prevalence of long bone fractures by bones affected for pooled samples (N/D=adults of undetermined sex).

Table 5.5.27 lists prevalence rates for all long bone fractures by sex. British and German females were more likely to fracture their fibulae than any other long bone. However, with the low overall fracture frequency among British females (0.26 percent), resulting in only one fractured fibula (0.71 percent), this might have occurred by chance. Three of 95 fibulae from German females (3.16 percent) and five of 86 fibulae from German males (5.81 percent) had sustained a fracture, making this the bone most often affected in pooled German samples. In contrast, British males had their clavicle fractured the most; nine of 109 male clavicles had experienced a fracture (8.26 percent).

	British samples						German samples					
	Female			Male			Female			Males		
	n	N	%	n	N	%	n	N	%	n	N	%
Clavicle	1	175	0.57	9	109	8.26	2	142	1.41	6	122	4.92
Humerus	0	179	0.0	0	131	0.0	0	195	0.0	1	165	0.61
Radius	1	159	0.63	0	122	0.0	1	137	0.73	6	117	5.13
Ulna	0	147	0.0	1	126	0.79	0	125	0.0	3	107	2.8
Femur	0	193	0.0	2	132	1.52	1	215	0.47	1	174	0.58
Tibia	0	170	0.0	0	130	0.0	2	185	1.08	7	149	4.7
Fibula	1	140	0.71	3	114	2.63	3	95	3.16	5	86	5.81
Total	3	1163	0.26	15	864	1.74	9	1094	0.82	29	920	3.15

Table 5.5.27 Prevalence of long bone fractures for pooled samples by bones affected.

Laterality of all fractures is tabulated in Table 5.5.28. While more upper limb bones from the left than the right side were fractured in the British samples (58.33 percent of left and 41.67 percent of right limb bone fractures), the contrary was observed for German samples. Here, 63.16 percent of all upper limb bone fractures occurred on the right side and 36.84 on the left. A marked difference was found for pooled British samples when fractures of the lower limb were analysed by side. More fractures occurred on the right side (83.33 percent), while only one fracture was seen on the left side (16.67 percent). Among German samples, the distribution for lower limb bone fractures was more balanced. Nine occurred on the left side (47.37 percent) and ten on the right side (52.63 percent). Upper and lower limb bone fractures were evenly distributed in the German samples (19 of 38 fractures, respectively). However, more upper than lower limb bone fractures were found in the British samples; twice as many occurred on the clavicles and arms (12 of 18 fractures) than the legs (6 of 18 fractures).

	British samples						German samples			
	Left		%	Right	%		Left	%	Right	%
Upper limb	7	58.33	5	41.67	Upper limb		7	36.84	12	63.16
Lower limb	1	16.67	5	83.33	Lower limb		9	47.37	10	52.63
Total GB	8	44.44	10	55.56	Total D		16	42.11	22	57.89

Table 5.5.28 Prevalence of long bone fractures by side affected for individuals with fractures.

Tables 5.5.29 and 5.5.30 provide information on age distribution of female and male individuals with long bone fractures for pooled British and German samples. However, since all but one fracture was healed, the age at death of each individual did probably not coincide with the age when the fracture was sustained. One female from Norton (NT23) had experienced a clavicle fracture, which was still healing at the time of death.

	Females	%	Males	%	Total	%
16-25	0	0.0	1	7.14	1	5.88
26-35	2	66.66	5	35.7	7	41.18
36-45	0	0.0	3	21.4	3	17.65
45+	1	33.33	5	35.7	6	35.29
Total	3	17.65	14	82.35	17	100.0

Table 5.5.29 Prevalence by age of long bone fractures for sexed British individuals with fractures.

	Females	%	Males	%	Total	%
16-25	1	14.29	1	4.76	2	7.14
26-35	3	42.86	7	33.33	10	35.71
36-45	3	42.86	7	33.33	10	35.71
45+	0	0.0	6	28.57	6	21.43
Total	7	25.0	21	75.0	28	100.0

Table 5.5.30 Prevalence by age of long bone fractures for sexed German individuals with fractures.

Results for the pooled sexes can be seen in Fig. 5.5.1. There was no apparent trend in the age distribution, although young adults in both countries had the lowest fracture frequency rates (5.88 percent and 7.14 percent). Young-middle adults showed a noticeable increase (41.18 percent and 35.71 percent), while middle-aged adults in the British samples had fewer fractures (17.65 percent). Rates for middle-aged German individuals were the same as in the previous age class. Old adult individuals from the British samples had their fracture prevalence approximately doubled compared to middle-aged adults (35.29 percent). Contrary to this, old adults from German samples showed a decrease in prevalence (21.43 percent).

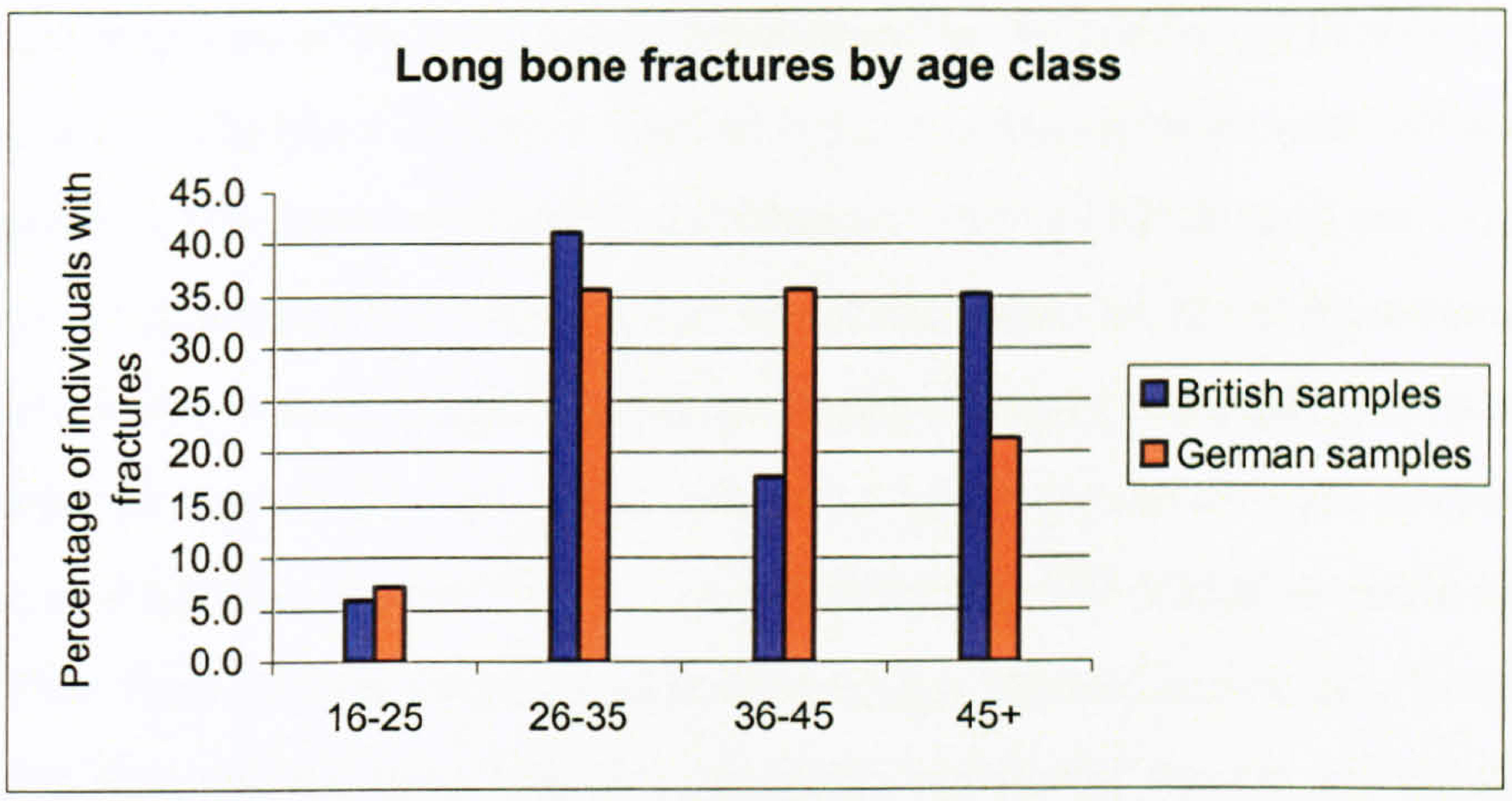


Fig. 5.5.1 Prevalence of long bone fractures by age class for female and male individuals with fractures.

The location of fractures within each long bone is tabulated in Table 5.5.31 and Fig. 5.5.2. In the British samples, almost three-quarters of all fractures occurred on the middle third of the diaphysis (72.22 percent), followed by the proximal third of diaphysis (16.67 percent) and the distal third (11.11 percent). In contrast, the majority of fractures in the German samples were located on the distal third of the diaphysis (44.74 percent). Slightly more than two-thirds of fractures were on the middle third (36.84 percent), while fewer fractures were seen on the proximal third (10.53 percent) and the proximal epiphysis (7.89 percent).

	British samples		German samples	
Proximal epiphysis	0	0.0	3	7.89
Proximal diaphysis	3	16.67	4	10.53
Middle diaphysis	13	72.22	14	36.84
Distal diaphysis	2	11.11	17	44.74
Total fractures	18	100.0	38	100.0

Table 5.5.31 Location of long bone fractures.

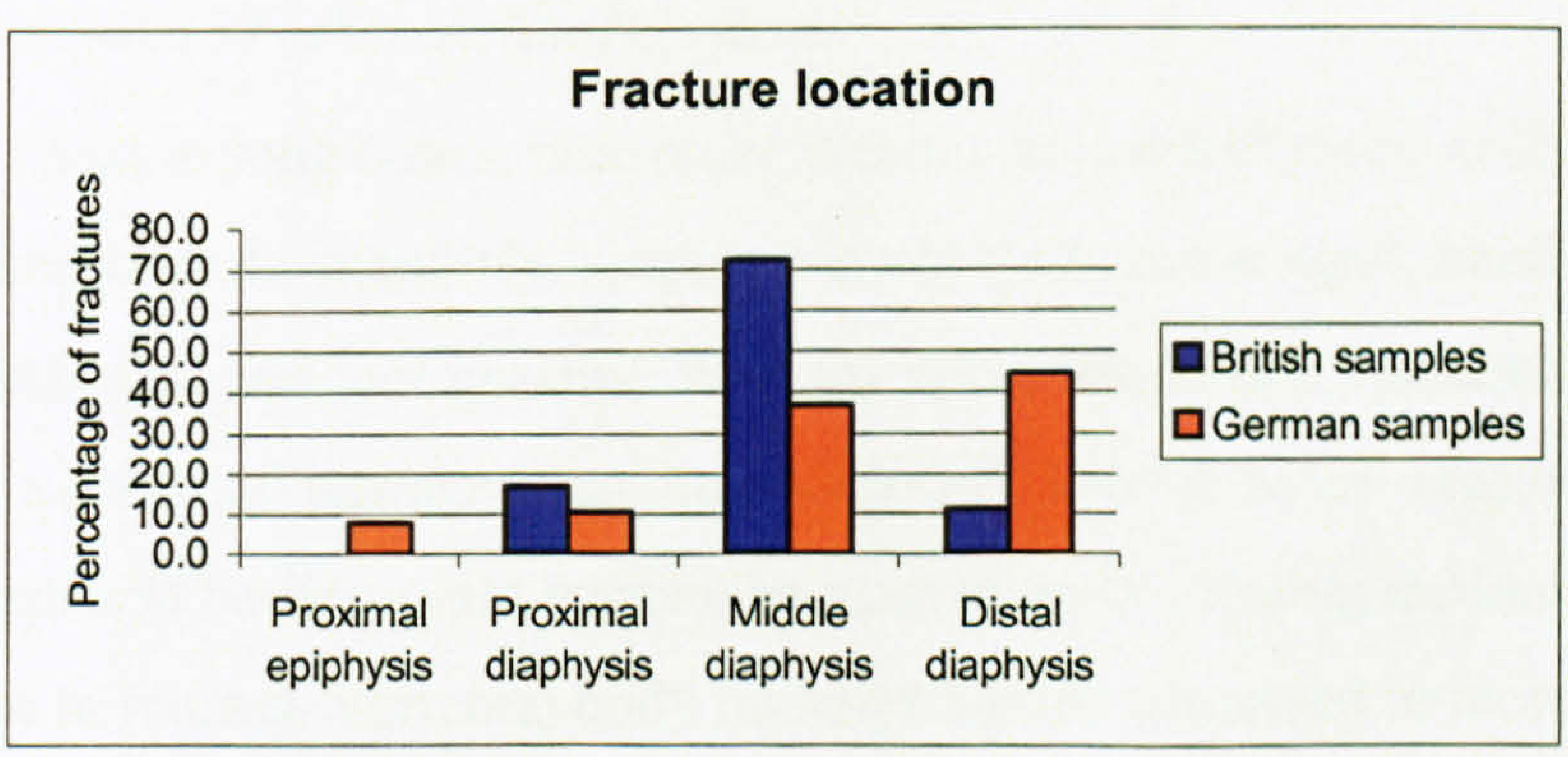


Fig. 5.5.2 Location of long bone fractures.

Descriptions of each fracture can be found in Appendix C5 (Table 1, Long bone fractures). The most common fracture type in both countries was oblique; only one transverse fracture was found in the English sample (AP28) and none occurred in the German individuals, although a number of fractures could not be assessed because the fracture line was no longer visible due to remodelling and radiography was not carried out for all fractured bones. In the British samples, eleven oblique fractures were present; one was a transverse and one a spiral fracture and five fractures could not be classified. All but three British fractures were healed; one showed active new bone formation suggesting that the bone was broken shortly before the female individual died (NT23). Two cases of non-union, both in the clavicle, indicated that the healing process was unsuccessful or had not happened yet because the person died (CS129 and CS180). More than three-quarters of the English fractures showed some degree of angulation or shortening (77.78 percent, or 14 of 18 fractures).

The majority of German fractures had well remodelled calluses and only ten fracture types could be identified; all were oblique. Only one male individual (PL116) had suffered a non-united fracture of the clavicle, resulting in a pseudoarthrosis. More than 80 percent of all fractures showed some angulation, rotation, pitting or secondary osteoarthritis (84.21 percent, or 32 of 38 fractures). Among these, two individuals, one female and one male, had evidence of more severe infections in the form of new bone formation and drainage sinuses (osteomyelitis), although the lesions had become remodelled (NU102 and PL131). One other male (PL71) might also have suffered post-traumatic osteomyelitis, having sustained a fracture of the femoral neck but developing osteomyelitis on the tibia and fibula of the same side where the fracture occurred.

Fractures of other skeletal elements

Next to long bones, nine other skeletal elements showed evidence of fractures. These comprised the mandible, scapula, vertebra, rib, metacarpal, hand phalanx, patella, metatarsal and foot phalanx. With the exception of ribs, metacarpals and vertebrae, other skeletal elements that did not classify as long bones were rarely fractured. Vertebral bodies might fracture because of an underlying metabolic disease as well as due to trauma. Vertebral body fractures will be discussed in more detail in the section on osteoporosis (see Metabolic disorders, 5.11.3 Osteoporosis) and results for prevalence rates are listed there. Since the mandible, scapula, hand and foot phalanges, metatarsals and patellae were infrequently affected, tables detailing prevalence were not produced. A list of all individuals with these fractures can be found in Appendix C5 (Table 2, Non-long bone fractures). All affected individuals were adults and all fractures had healed before the individuals died.

Mandible fractures

In total three individuals showed evidence of mandibular fractures. One individual each belonged to the British samples of Castledyke South (CS78) and Norton (NT69) and both were males, the first middle-aged, the second a young-middle adult. The third individual, also a young-middle aged male, came from the German site of Neresheim (NE10). Prevalence rates for male individuals for the respective sites by number of individuals with their mandible preserved were 4.0 percent at Castledyke South (1 of 25 males), 10.0 percent at Norton (1 of 10 males) and 3.33 percent at Neresheim (1 of 30 males). The overall prevalence for all adults from pooled British samples was 1.25 percent (2 of 160 individuals), and for pooled German samples it was 0.4 percent (1 of 247 individuals).

Scapula fractures

One middle-aged male from Pleidelsheim (PL116) had sustained a fracture to the blade of his left scapula. The prevalence for this kind of fracture was 3.23 percent for males from Pleidelsheim with both their scapulae preserved (1 of 31 males). The overall prevalence for German individuals was 0.71 (1 of 140 individuals), while none of 180 British individuals had their scapulae fractured. With regard to the actual number of scapulae preserved, the prevalence was 1.67 percent for Pleidelsheim males (1 of 60 scapulae) or 0.33 percent for all scapulae from German samples (1 of 301 scapulae); none of the 296 preserved British scapulae showed evidence of fractures.

Vertebral fractures

Fractures other than those which occurred on vertebral bodies (see 5.11.3 Osteoporosis,) were rare and only two individuals were affected. A young-middle aged male from Castledyke South (CS21) had a so-called clay-shoveller's fracture affecting the spinous process of the first thoracic vertebra (T1). The prevalence for males from Castledyke South for clay shoveller's fracture was 4.55 percent (1 of 22 males with the spinous process of T1 present) or 0.82 percent for all British T1 with spinous processes (1 of 122 T1). None of the 107 spinous processes at the level of T1 from German samples was affected.

An old adult female from Neresheim (NE81) showed a fracture of both superior articular facets of the fifth lumbar vertebra (L5). This resulted in a frequency of 4.0 cent (1 of 25 females with L5) for all females with superior facets of L5 preserved or a total of 0.77 percent with regard to all L5 with superior facets in the German samples (1 of 130 L5). None of 149 British L5s with superior facets present was affected.

Rib fractures

Prevalence rates for rib fractures by individuals affected from British sites, as well as for pooled British samples, can be seen in Table 5.5.32. All three British samples had a similar frequency of rib fractures with regard to individuals affected, resulting in an overall prevalence of 7.25 percent. With regard to the actual number of ribs preserved, a different picture was established (Table 5.5.33). Apple Down had a considerable higher prevalence of rib fractures (1.83 percent), than at the other two British sites. At Norton, the prevalence was 0.4 percent and at Castledyke South, 0.27 percent of ribs were involved. The overall prevalence for pooled British samples was 1.01 percent.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	3	37	8.11	2	27	7.41	2	12	16.67	7	76	9.21
Males	2	27	7.41	1	20	5.0	0	9	0.0	3	56	5.36
N/D	0	1	0.0	0	0	0.0	0	3	0.0	0	4	0.0
Total	5	64	7.81	3	50	6.0	2	24	8.33	10	138	7.25

Table 5.5.32 Prevalence of rib fractures by individuals affected for individual sites and pooled British samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	18	746	2.41	2	607	0.33	2	268	0.75	22	1621	1.36
Males	7	599	1.17	1	491	0.2	0	171	0.0	8	1261	0.63
N/D	0	18	0.0	0	27	0.0	0	56	0.0	0	101	0.0
Total	25	1363	1.83	3	1125	0.27	2	495	0.4	30	2983	1.01

Table 5.5.33 Prevalence of rib fractures by ribs affected for individual sites and pooled British samples (n=number of ribs affected, N=number of ribs observable, N/D=adults of undetermined sex).

Rib fracture prevalence for individual German sites and pooled samples by individuals affected are tabulated in Table 5.5.34. Although the overall prevalence was similar to the result for pooled British samples, 7.69 percent, individual frequencies varied among the sites. There was no statistically significant difference between British and German individuals with rib fractures in the two pooled samples (χ^2=0.0033, p=0.9541, d.f.=1).

Nusplingen had a high rate of fractured ribs, with half of all individuals affected. However, the number of individuals with well preserved ribs was very low. At Neresheim, 6.4 percent and at Pleidelsheim, 2.63 percent had suffered one or more fractured ribs. Results for rib fractures by ribs affected at German sites and pooled German samples can be found in Table 5.5.35. Compared to British sites, overall prevalence was only half as high, with 0.49 percent affected. Again, Nusplingen had the highest prevalence, but also the lowest number of preserved ribs (2.23 percent). At Neresheim, 0.41 percent and at Pleidelsheim, 0.11 percent of ribs were fractured.

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	2	27	7.41	0	3	0.0	0	21	0.0	2	51	3.92
Males	1	20	5.0	3	3	100.0	1	16	6.25	5	39	12.82
N/D	0	0	0.0	0	0	0.0	0	1	0.0	0	1	0.0
Total	3	47	6.4	3	6	50.0	1	38	2.63	7	91	7.69

Table 5.5.34 Prevalence of individuals with rib fractures by individuals affected for individual sites and pooled German samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	3	463	0.65	0	127	0.0	0	486	0.0	3	1076	0.28
Males	0	267	0.0	5	97	5.15	1	378	0.26	6	742	0.81
N/D	0	0	0.0	0	0	0.0	0	14	0.0	0	7	0.0
Total	3	730	0.41	5	224	2.23	1	878	0.11	9	1825	0.49

Table 5.5.35 Prevalence of rib fractures by ribs affected for individual sites and pooled German samples (n=number of ribs affected, N=number of ribs observable, N/D=adults of undetermined sex).

Table 5.5.36 tabulates prevalence for rib fractures by side affected. Ribs from the left side were slightly more often fractured in British samples, but the difference was minor with 0.73 percent of left ribs and 0.61 percent of right ribs involved. Among German samples, right ribs were more than twice as often fractured than ribs from the left side (0.54 percent of right and 0.22 percent of left ribs).

	British samples						German samples					
	L side			R side			L side			R side		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	11	817	1.35	6	804	0.75	2	514	0.39	0	562	0.0
Males	0	642	0.0	3	619	0.48	0	383	0.0	5	359	1.39
N/D	0	43	0.0	0	58	0.0	0	7	0.0	0	7	0.0
Total	11	1502	0.73	9	1481	0.61	2	904	0.22	5	928	0.54

Table 5.5.36 Prevalence of rib fractures by side affected for pooled British and German samples (n=number of ribs affected, N=number of ribs observable, N/D=adults of undetermined sex).

Metacarpal fractures

Five individuals from two of the British samples – Apple Down and Castledyke South – had five fractured metacarpals. Prevalence rates for metacarpal fractures by individuals affected can be found in Table 5.5.37, and Table 5.5.38 lists frequencies by bones affected. A total of 3.13 percent of all British individuals had experienced a fractured metacarpal. Males were more than twice as likely to feature a fracture of this bone than females; 4.55 percent and 2.2 percent, respectively. With regard to the overall number of metacarpal bones preserved, the prevalence for pooled British samples was 0.35 percent. Again, males had twice the frequency of females; 0.51 percent and 0.25 percent, respectively.

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	1	44	2.27	1	36	2.78	0	11	0.0	2	91	2.2
Males	1	30	3.33	2	29	6.9	0	7	0.0	3	66	4.55
N/D	0	1	0.0	0	1	0.0	0	1	0.0	0	3	0
Total	2	75	2.67	3	66	4.55	0	19	0.0	5	160	3.13

Table 5.5.37 Prevalence of metacarpal fractures by individuals affected for individual sites and pooled British samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	1	366	0.27	1	294	0.34	0	129	0.0	2	789	0.25
Males	1	285	0.35	2	216	0.93	0	82	0.0	3	583	0.51
N/D	0	10	0.0	0	15	0.0	0	23	0.0	0	48	0.0
Total	2	661	0.30	3	525	0.57	0	204	0.0	5	1420	0.35

Table 5.5.38 Prevalence of metacarpal fractures by metacarpals affected for individual sites and pooled British samples (n=number of metacarpals affected, N=number of metacarpals observable, N/D=adults of undetermined sex).

German individuals were less likely to have a fractured metacarpal, with only two individuals from Pleidelsheim affected (Table 5.5.39), resulting in an overall prevalence of 1.71 percent. Only men had their metacarpals fractured, leading to a similar prevalence as for British males; 4.08 percent. Prevalence by bones affected is tabulated in Table 5.5.40 and a total of 0.2 percent of all metacarpals were fractured. With regard to male metacarpals, a frequency of 0.45 percent was found. As not all metacarpal bones preserved could be identified by side, laterality was not considered.

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	29	0.0	0	10	0.0	0	25	0.0	0	64	0.0
Males	0	16	0.0	0	9	0.0	2	24	8.33	2	49	4.08
N/D	0	0	0.0	0	2	0.0	0	2	0.0	0	4	0.0
Total	0	45	0.0	0	21	0.0	2	51	3.92	2	117	1.71

Table 5.5.39 Prevalence of metacarpal fractures by individuals affected for individual sites and pooled German samples (n=number of individuals affected, N=number of individuals observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	N	N	%	n	N	%	n	N	%
Females	0	229	0.0	0	77	0.0	0	220	0.0	0	526	0.0
Males	0	151	0.0	0	62	0.0	2	234	0.85	2	447	0.45
N/D	0	0	0.0	0	11	0.0	0	16	0.0	0	27	0.0
Total	0	380	0.0	0	150	0.0	2	460	0.43	2	990	0.2

Table 5.5.40 Prevalence of metacarpal fractures by metacarpals affected for individual sites and pooled German samples (n=number of metacarpals affected, N=number of metacarpals observable, N/D=adults of undetermined sex).

Hand phalanx fractures

One young-middle aged female from the British site of Apple Down (AP41B) had fractured an unsided intermediate hand phalanx at the proximal diaphysis. The fracture had never healed properly, thus forming a pseudoarthrosis. In addition, the distal joint had fused to the distal phalanx. This was most likely caused by trauma as no signs of infection were observed. The prevalence for these hand phalanx fractures for females from Apple Down was 2.94 percent (1 of 34 females) or 1.64 percent of all adults from this site (1 of 64 individuals). With regard to intermediate hand phalanges preserved, the true prevalence was 0.42 percent for females (1 of 239 female intermediate hand phalanges) or 0.23 percent for all intermediate hand phalanges from Apple Down (1 of 442 intermediate hand phalanges). As a total of 73 individuals from the pooled British samples had their intermediate hand phalanges preserved, the prevalence was 1.37 percent (1 of 73 individuals). With regard to the total number of intermediate hand phalanges present, the frequency was 0.15 percent (1 of 650 intermediate hand phalanges) for British adults. None of the 679 intermediate hand phalanges from German samples was affected. However, two individuals, one young-middle age female (PL47) and one middle-aged male (PL104) from Pleidelsheim had fractured a proximal hand phalanx. The prevalence was 7.69 percent for females (1 of 13 females) and 9.09 percent for males from Pleidelsheim (1 of 11 males). When the total number of proximal hand phalanges at Pleidelsheim was considered, prevalence for females was 0.84 percent (1 of 119 female proximal hand phalanges) and 0.91 percent for males (1 of 110 male proximal hand phalanges). As two of a total of 519 proximal hand phalanges from the pooled German samples were fractured, the overall frequency was 0.39 percent. None of 1,142 proximal hand phalanges from the pooled British sites was affected.

Patella fractures

Two female individuals, both from the German site of Pleidelsheim, displayed a fracture of the patella. One young-middle age female (PL13) had her right patella involved, and the other, an old adult female (PL98), had fractured her left patella. The prevalence for females from Pleidelsheim was 8.0 percent (2 of 25 females with patellae), or 2.38 percent for pooled samples (2 of 84 individuals with patellae). With regard to the total number of patellae preserved for females from Pleidelsheim, frequency was 2.08 percent (2 of 96 patellae), or 0.87 percent for all patellae from pooled German sites (2 of 231 patellae). None of 239 patellae from the pooled British samples was affected.

Metatarsal fractures

Fractures of the metatarsal bones were found in three individuals. One was a young-middle aged female from Neresheim (NE133), who showed a fracture of the right second metatarsal; the other two, a young-middle aged male (PL111) and a middle-aged male, both from Pleidelsheim (PL116), had sustained fractures of the right third metatarsal and the left second and third metatarsal, respectively. The prevalence for individuals affected was 2.27 percent for females from Neresheim (1 of 44 females) and 5.71 percent for males from Pleidelsheim (2 of 35 males). For pooled German samples, the prevalence was 1.68 percent (3 of 179 individuals). With regard to the actual number of metatarsal bones preserved, the prevalence of female metatarsal fractures at Neresheim was 0.27 percent (1 of 374 metatarsals), while male prevalence was 0.9 percent (3 of 332 metatarsals). Overall frequency for pooled German samples was 0.32

(4 of 1,257 metatarsals). None of 1,404 metatarsal bones from pooled British sites was affected.

Foot phalanx fractures

An old adult male from Pleidelsheim (PL111) had a fractured left proximal foot phalanx of the first digit. The prevalence of foot phalanx fractures for males from Pleidelsheim was 10.0 percent for individuals (1 of 10 individuals) or 4.35 percent for all individuals with proximal foot phalanges present from Pleidelsheim (1 of 23 individuals). For pooled German sites, this prevalence was 2.63 percent (1 of 38 individuals). A total of 414 proximal foot phalanges were preserved from the three German sites, resulting in a fracture prevalence of 0.24 percent (1 of 414 proximal foot phalanges). None of 808 proximal foot phalanges from British sites was affected.

5.5.2 Cranial trauma

No individual under the age of 16 years had experienced cranial injuries: Therefore, all prevalence rates were calculated for adult individuals and individuals with healed and unhealed cranial injuries are listed in Appendix C5, Table 3. Prevalence for blunt and sharp force cranial injuries for individual sites and pooled British samples by individuals affected are tabulated in Table 5.5.41; prevalence rates for individual sites and pooled German can be found in Table 5.5.42. The disparity in frequencies of cranial trauma is apparent: only three British individuals displayed evidence of cranial injuries (1.94 percent). In contrast, 18 German skeletons were affected by single or multiple cranial injuries (7.41 percent). Although the number of British individuals with cranial injuries was too small to allow for chi-squared testing, German individuals were more than three times more often affected and, even without a statistical confirmation, this appears to be a significant difference. In each of the three British samples, one individual was affected. Since the number of individuals with preserved skulls was the lowest at Norton, the highest prevalence for cranial trauma occurred (3.23 percent). At Castledyke South, 1.92 percent of individuals with preserved skulls were affected and at Apple Down, this rate was 1.43 percent. Among German samples, the highest prevalence of cranial trauma was seen at Nusplingen, with 10.0 percent of all individuals with skulls affected. At Pleidelsheim, 5.71 percent of all adult skulls had sustained cranial injuries and almost the same prevalence was found at Neresheim with

5.26 percent. One woman and two men from the British samples were affected by cranial trauma and the female to male ratio was 1:2. However, with only three individuals involved, this might be meaningless. A clear male dominance was found among German samples. Here, three females and 15 males were affected, resulting in a ratio of 1:5. Consequently, a chi-squared test revealed that the difference between male and female prevalence rates in the German sample was statistically significant (χ^2=9.4106, p=0.0021, d.f.=1). Likewise, British males had experienced statistically significantly fewer cranial injuries compared to German males (χ^2=4.2764, p=0.0386, d.f.=1).

	Apple Down			Castledyke South			Norton			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	41	0.0	1	24	4.2	0	22	0.0	1	87	1.15
Males	1	28	3.57	0	28	0.0	1	6	16.67	2	62	3.23
N/D	0	1	0.0	0	0	0.0	0	3	0.0	0	4	0.0
Total	1	70	1.43	1	52	1.92	1	31	3.23	3	153	1.96

Table 5.5.41 Percentage of individuals with cranial injuries by skulls affected for pooled British samples (n=number of skulls affected, N=number of skulls observable, N/D=adults of undetermined sex).

	Neresheim			Nusplingen			Pleidelsheim			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	44	0.0	3	45	6.67	0	36	0.0	3	125	2.4
Males	4	32	12.5	7	53	13.21	4	33	12.12	15	118	12.71
N/D	0	0	0.0	0	2	0.0	0	1	0.0	0	3	0.0
Total	4	76	5.26	10	100	10.0	4	70	5.71	18	246	7.32

Table 5.5.42 Percentage of individuals with cranial injuries by skulls affected for pooled German samples (n=number of skulls affected, N=number of skulls observable, N/D=adults of undetermined sex).

Four individuals had sustained multiple cranial injuries; one male from Norton (NT55-1), two men from Neresheim (NE32 and NE141-1) and one woman from Nusplingen (NU209) were affected. Of these individuals, one male had four lesions, whereas each of the other three individuals had two injuries. In addition, one male from Nusplingen (NU169) had two bones affected by the same lesion. As only four individual injuries were found among the British samples, results were pooled and they can be seen in Table 5.5.43. Left parietal bones were most often involved (1.05 percent). Frontal and right parietal bones showed equal prevalence rates with 0.53 percent and 0.54 percent, respectively. None of the 183 occipital bones displayed cranial trauma.

	Frontal			L parietal			R parietal			Occipital		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	0	112	0.0	0	114	0.0	1	110	0.91	0	105	0.0
Males	1	70	1.43	2	71	2.82	0	70	0.0	0	73	0.0
N/D	0	5	0.0	0	5	0.0	0	6	0.0	0	5	0.0
Total	1	187	0.53	2	190	1.05	1	186	0.54	0	183	0.0

Table 5.5.43 Percentage of individuals with cranial injuries by cranial bones affected for pooled British samples (n=number of cranial bones affected, N=number of cranial bones observable, N/D=adults of undetermined sex).

Results for pooled German cranial injuries can be seen in Table 5.5.44. The 18 German individuals had a total of 23 isolated lesions located on 25 cranial bones; two individuals (NU169 and PL82) had one lesion affecting two bones. Among German individuals, the left parietal bone was predominantly affected (4.24 percent), followed by the frontal bone (2.35 percent) and the left parietal bone (1.77 percent). Only one occipital bone was affected by trauma (0.38 percent). More than half of all lesions were found on the left parietal bone (52.17 percent, or 12 of 23 lesions), almost one-third were located on the frontal bone (30.44 percent, or 7 of 23 lesions) and more than one-fifth were on the right parietal bone (21.74 percent, or 5 of 23 lesions). The occipital bone was affected to a low extent (4.35 percent, 1 of 23 lesions).

	Frontal			L parietal			R parietal			Occipital		
	n	N	%	n	N	%	n	N	%	n	N	%
Females	1	152	0.66	1	144	0.69	1	144	0.69	0	134	0.0
Males	6	139	4.32	10	134	7.46	4	134	2.99	1	128	0.78
N/D	0	7	0.0	0	5	0.0	0	5	0.0	0	5	0.0
Total	7	298	2.35	12	283	4.24	5	283	1.77	1	267	0.38

Table 5.5.44 Percentage of individuals with cranial injuries by cranial bones affected for pooled German samples (n=number of cranial bones affected, N=number of cranial bones observable, N/D=adults of undetermined sex).

The type of injury (blunt or sharp force), and a possible correlation of injury type with healed and unhealed trauma, was analysed and the results can be seen in Table 5.5.45. As no unhealed blunt force injuries were found and adults of undetermined sex were not affected, these two categories were omitted. One British individual (NT55-1) was affected by two different types of injuries – healed blunt and sharp force. Again, the low number of lesions observed in the British samples was likely to make analysis of results obsolete. However, all four lesions were healed, and so were all but two of the four lesions encountered by German females. Both healed lesions were blunt force injuries and the perimortem trauma was inflicted by an edged weapon. German males had slightly more healed blunt trauma (26.09 percent), than healed sharp force injuries (21.74 percent). However, the majority of lesions were classified as unhealed sharp force trauma (34.78 percent). The same trend of slightly more unhealed sharp force lesions was seen when female and male cranial injuries were pooled. However, three of the 18 German individuals had multiple injuries and, with regard to individuals affected, the most commonly found type of injury was healed blunt trauma (44.44 percent, or 8 of 18 individuals), while healed and unhealed sharp force trauma occurred in equal proportion (27.78 percent, or 5 of 18 lesions).

	Healed blunt force			Healed sharp force			Unhealed sharp force			Total		
	n	N	%	n	N	%	n	N	%	n	N	%
British females	1	4	25.0	0	4	0.0	0	4	0.0	1	4	25.0
British males	2	4	50.0	1	4	25.0	0	4	0.0	3	4	75.0
Total GB	3	4	75.0	1	4	25.0	0	4	0.0	4	4	100.0
German females	2	23	8.7	0	23	0.0	1	23	4.35	4	23	17.39
German males	6	23	26.09	5	23	21.74	8	23	34.78	19	23	82.61
Total D	8	23	34.78	5	23	21.74	9	23	39.13	23	23	100.0

Table 5.5.45 Prevalence of injury type in relation to healed and unhealed cranial trauma (n=number of injuries per type, N=overall number of lesions).

As age of onset of healed lesions cannot be assessed, only the age of individuals with unhealed trauma was analysed. A total of five skeletons from the German sites of Neresheim and Nusplingen showed unhealed sharp force trauma; one woman and four men. Three had multiple injuries, while two had single lesions. Three individuals were young-middle aged, one was middle-aged and one was an old adult.

5.5.6 Spondylolysis and spondylolisthesis

Only adult individuals displayed evidence of spondylolysis. Frequencies for the individual samples are presented by sex and can be found in Table 5.5.46. In addition, all individuals affected by spondylolysis were listed in Appendix C5, Table 4.

The discrepancy between the number of individuals with spondylolysis and the number of vertebrae with the lesion is due to the involvement of more than one vertebra in some individuals. At Apple Down, only female adults had sustained vertebral lesions recognized as spondylolysis (18.75 percent); in contrast only males were affected at Norton (18.18 percent). Castledyke South had a higher female (18.92 percent) than male involvement (14.3 percent) and here the total number of adults with the lesion is the highest for the three British samples (17.24 percent). For all three German samples, differences in spondylolysis between the sexes were less marked. Neresheim (12.2 percent) and Pleidelsheim (10.4 percent) had a similar overall prevalence, while Nusplingen displayed the highest rate (33.33 percent). The percentage of individuals with spondylolysis of the lumbar spine in the combined samples for each country is almost identical, with 12.95 percent for the English skeletons and 13.86 percent for the German skeletal remains. For individual sites, frequencies vary, although only two skeletal samples – Castledyke South and Nusplingen – differ from the frequency of approximately 10-12 percent observed at the other four sites. However, the number of individuals with preserved lumbar spines at Nusplingen was low. Females in both countries had a higher prevalence of spondylolysis than males, but no statistically significant differences, neither between nor within the samples, were detected (British females and males: χ^2=2.0365, p=0.1536, d.f.=1; German females and males: χ^2=0.0190, p=0.8905, d.f.=1; British and German females: χ^2=0.1916, p=0.6616, d.f.=1; British and German males: χ^2=0.5900, p=0.4424, d.f.=1).

British	Apple Down			Castledyke South			Norton			Total GB		
samples	n	N	%	n	N	%	n	N	%	n	N	%
Females	6	32	18.75	7	37	18.92	0	7	0.0	13	76	17.11
Males	0	26	0.0	3	21	14.3	2	11	18.18	5	58	8.62
N/D	0	1	0.0	0	0	0.0	0	4	0.0	0	5	0.0
Total	6	59	10.17	10	21	17.24	2	22	9.09	18	139	12.95
German	Neresheim			Nusplingen			Pleidelsheim			Total D		
samples	n	N	%	n	N	%	n	N	%	n	N	%
Females	3	23	13.0	2	8	25.0	3	25	12.0	8	56	14.29
Males	2	18	11.11	2	4	50.0	2	23	8.7	6	45	13.33
N/D	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
Total	5	41	12.2	4	12	33.33	5	48	10.4	14	101	13.86

Table 5.5.46 Lumbar spondylolysis for individual sites by individuals affected (n=number of individuals affected, N=number of individuals with lumbar spine preserved, N/D=adults of undetermined sex).

Frequencies for individual vertebrae from pooled British samples are tabulated in Table 5.5.47 and results for pooled German samples can be found in Table 5.5.48. Only one male individual from England and Germany, respectively, presented a non-lumbar vertebra with neural arch separation. In both cases, the last thoracic vertebra (T12) was affected and the overall frequency for individuals is 1.01 percent and 2.22 percent for England and Germany, respectively. The distribution of lesions in females from both countries is confined to the last three lumbar vertebrae. With the exception of the sixth lumbar vertebra, which was only affected in British males, L5 was most often involved, followed by L4. Despite some variation in prevalence within individual subgroups, overall prevalence was similar; in British samples, it ranged between 2.03 percent for males and 2.91 percent for females. German females had a marginally higher frequency, with 2.82 percent, to German males, with 2.73 percent. This resulted in an overall prevalence (including vertebrae of adults of undetermined sex) of 2.45 percent for British populations and 2.78 percent for German samples.

	Females			Males			N/D			Total GB		
	n	N	%	n	N	%	n	N	%	n	N	%
T12	0	62	0.0	1	51	1.96	0	3	0.0	1	116	0.86
L1	0	68	0.0	1	56	1.79	0	3	0.0	1	127	0.79
L2	2	80	2.5	0	60	0.0	0	4	0.0	2	144	1.39
L3	0	79	0.0	0	56	0.0	0	4	0.0	0	139	0.0
L4	1	71	1.41	1	60	1.67	0	5	0.0	2	136	1.47
L5	10	85	11.77	3	58	5.17	0	5	0.0	13	148	8.78
L6	0	1	0.0	1	4	25.0	0	0	0.0	1	5	20.0
Total	13	446	2.91	7	345	2.03	0	24	0.0	20	815	2.45

Table 5.5.47 Prevalence of spondylolysis for pooled British samples by number of affected vertebrae (n=number of affected vertebrae, N=number of observable vertebrae, N/D=adults of undetermined sex).

	Females			Males			N/D			Total D		
	n	N	%	n	N	%	n	N	%	n	N	%
T12	0	54	0.0	1	38	2.63	0	0	0.0	1	92	1.09
L1	0	55	0.0	0	41	0.0	0	0	0.0	0	96	0.0
L2	0	59	0.0	0	48	0.0	0	0	0.0	0	107	0.0
L3	1	59	1.69	0	48	0.0	0	0	0.0	1	107	0.94
L4	4	62	6.45	3	60	5.0	0	0	0.0	7	122	5.74
L5	5	65	7.69	4	58	6.9	0	1	0.0	9	124	7.26
L6	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0
Total	10	354	2.82	8	293	2.73	0	1	0.0	18	648	2.78

Table 5.5.48 Prevalence of spondylolysis for pooled German samples by number of affected vertebrae (n=number of affected vertebrae, N=number of observable vertebrae, N/D=adults of undetermined sex).

Fig. 5.5.3 provides information on the distribution of affected vertebrae within the pooled samples. Of the 20 lesions in the British populations, one (5.0 percent) was found each on T12, L1 and L6, and two (10.0 percent) on L2 and L4; with 13 cases of spondylolysis, L5 was affected the most (65.0 percent). Four of these 20 vertebrae (20.0 percent) with spondylolysis were unilateral lesions. Three lesions occurred on the right and one on the left *pars interarticularis*. The 18 vertebrae with spondylolysis from the combined German sites showed a slightly different distribution, with L4 more often affected than in the British samples (38.89 percent). T12 and L3 were the least affected with one vertebra each (5.56 percent), and half of all lesions occurred on L5. Three of the 18 lesions were unilateral (16.67 percent) and all were situated on the right side.

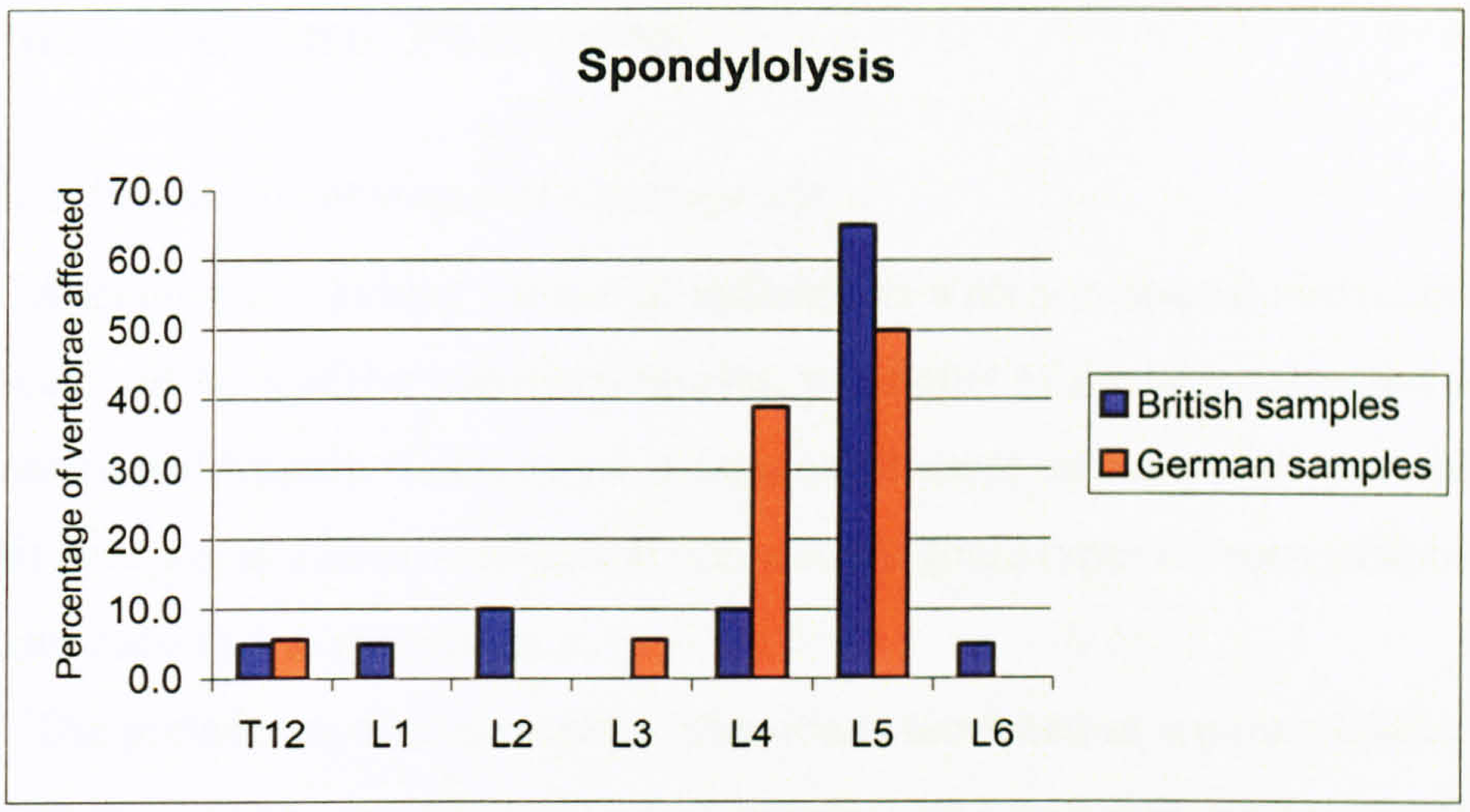


Fig. 5.5.3 Prevalence of spondylolysis by sex and affected vertebrae (T12=12th thoracic vertebra, L1-5=1st-5th lumbar vertebrae).

In individuals with spondylolysis the involvement of more than one vertebra was relatively common. Two males, one from Castledyke South, and the other from Norton, had two vertebrae with spondylolysis, but four individuals from the German sites – two females and two males – had spondylolysis of the fourth and fifth lumbar vertebrae. Four British individuals had experienced complications due to spondylolysis, with forward slipping of the fifth lumbar vertebra on the sacral base, a condition known as spondylolisthesis. In British samples, spondylolisthesis was found in three females and one male. A total of 22.22 percent (4 of 18 individuals) of British individuals with spondylolysis were affected. In contrast, only one German skeleton, a male, displayed this condition (11.11 percent, or 1 of 9 individuals). More than one-quarter of British individuals, (27.78 percent, or 5 of 18 individuals with sacra present) had congenital anomalies in addition to spondylolysis. For German individuals, this was observed for more than one-fifth (22.22 percent, or 2 of 9 individuals with sacra present) of all skeletons with spondylolysis. However, of the 14 British individuals with spina bifida occulta, three had spondylolysis (21.4 percent), whereas one of 13 German individuals with spina bifida occulta also had spondylolysis (7.69 percent). As not all skeletons had lumbar spines and sacra preserved, the numbers of affected individuals differed.

5.6 Non-specific infections

5.6.1 Periostitis, osteitis and osteomyelitis

Appendix C6, Tables 1-6 list all individuals with non-specific infection apart from focal infections of the maxillary sinuses, periostitis of the visceral aspect of ribs and endocranial lesions. Cases of periostitis, osteitis and osteomyelitis were not separated in this analysis as a clear recognition between the three types of bone infection is difficult in archaeological specimens.

The prevalence of non-specific infection is tabulated in separate tables. Tables 5.6.1 (British samples) and 5.6.2 (German samples) give prevalence rates by affected skeletal elements (bone count). Since there were no statistically significant differences in left and right side frequencies for the combined samples of both countries (British samples: χ^2=0.2206, p=0.6386, d.f.=1; German samples: χ^2=16.46, p=0.0000, d.f.=1), findings for paired bones were combined. Additionally, Tables 5.6.3 (British samples) and 5.6.4 (German samples) display results for non-specific infection by individuals.

The bone most often involved in inflammatory responses in the pooled British and German skeletons was the tibia with 29 of 398 observable tibiae (7.29 percent) and 62 of 432 tibiae (14.35 percent), respectively. On an individual level, 11.8 percent of all British skeletons with both their tibiae preserved and almost one-quarter (24.87 percent of German skeletons had signs of infection on this bone. The second-most involved bone was the fibula, again in both countries and, again, on an individual level as well as by skeletal element count. Thirteen of the 334 fibulae (3.89 percent) present in the combined British samples and 26 of 237 fibulae (10.97 percent) derived from the German samples showed signs of infectious bone response. Although individuals in both countries shared the same pattern of high lower leg involvement, prevalence for the German individuals was significantly higher compared to the British samples and frequencies for tibiae and fibulae were found to be statistically significant (tibia: χ^2=10.4522, p=0.0012, d.f.=1; fibula: χ^2=13.0166, p=0.0003, d.f.=1).

With few exceptions, individuals from the German samples were more likely to show reactive new bone response to inflammatory processes or trauma than their British counterparts. The exceptions are the humerus and radius, the bones of the hands (metacarpals and proximal hand phalanges), as well as the foot bones (metatarsals and proximal foot phalanges), when focussing on the skeletal elements present. However, these differences are minimal and do not exist on an individual level, where in the

British samples only the proximal hand phalanges were more often affected. This is also reflected in the range of skeletal elements affected. Of the 20 bones listed in Tables 5.6.1 and 5.6.2, six skeletal elements (maxilla, palate, sacrum, manubrium, talus and calcaneus) were not involved in inflammatory responses in the British samples, while only one element (proximal hand phalanges) was not represented in the German skeletons. These discrepancies became more evident when concentrating on the non-adult sub-samples from both countries. British non-adults had not developed any reactive new bone formation or other inflammatory responses apart from on the maxillary sinuses (see 5.6.2 Chronic maxillary sinusitis), whereas German non-adults had suffered from infectious responses on five different skeletal elements, namely on their maxillae (6.35 percent), cranium (3.7 percent), palate halves (3.57 percent), clavicle (2.08 percent) and femur (1.39 percent). Equally, females from the British samples had only a few skeletal elements involved in periosteal reactions (crania, radii, tibiae and fibulae), and only in two areas of the body – the cranium and radius – prevalence exceeded that found in German females, who displayed a wider range of bones affected. However, numbers of females affected on an individual level were low in both countries with the exception of the tibiae and fibulae. The highest prevalence was found on the tibiae of females from Britain and Germany, when considering the number of bones present as well as the number of individuals with both tibiae observable. Eight of 171 British female tibiae (4.68 percent) and 23 of 194 German female tibiae showed bone changes. Prevalence for the fibula was lower with five of 141 British female fibulae (3.55 percent) and 4 of 105 German female fibulae (3.81 percent) involved. Concentrating on the number of females with lower leg involvement, British females showed similar frequencies for the two lower leg bones – 8.22 percent of tibiae and 6.67 percent of fibulae present. In contrast, German females not only had a higher prevalence of lower leg bones affected but also a marked difference in the frequencies observed for the tibia and fibula. More than twice as many women with their tibiae present (20.93 percent) had some bone reaction, while only 10.0 percent had changes on their fibulae. Females from the German samples had a statistically significantly higher prevalence of tibial reactions than their British counterparts (χ^2=4.9778, p=0.0257, d.f.=1).

Compared to non-adults and females, males were the sub-sample most often showing bone changes caused by inflammatory responses. However, some differences were present between the two countries. British males had fewer skeletal elements affected than German males, who showed a wider range of elements involved. For several bones British male frequencies were similar or slightly higher compared to prevalence rates of German males. Nevertheless, German males had experienced higher frequencies for the ilium and sacrum (7.35 percent of iliac halves and 7.14 percent of sacra). Even more striking was the difference between the numbers of fibulae affected. Newly formed bone on fibulae of German males had a prevalence of 22.92 percent, while 6.84 percent of the British male fibulae showed periosteal reactions. On an individual level, a significantly higher proportion of German males had their fibulae involved (χ^2=11.5142, p=0.0007, d.f.=1), while the difference was statistically not significant regarding the tibiae (χ^2=2.7551, p=0.0969, d.f.=1). The difference between female and male tibial changes was tested by country and was found to have a statistically significant value in British and German samples with males having higher rates than females (British samples: χ^2=6.0853, p=0.0136, d.f.=1; German samples: χ^2=4.8124, p=0.0283, d.f.=1). Finally, to summarize the described observations, it is apparent that higher proportions of males in both countries had experienced reactive new bone formation while females were less often affected. Only German non-adults showed evidence of periosteal reactions. In general, German individuals displayed more changes, while the tibia was the bone most often involved in females from both countries and in British males, whereas the fibula had more osseous changes in German males.

Skeletal element	Subadults n/N (%)	Females n/N (%)	Males n/N (%)	N/D n/N (%)	Total n/N (%)
Cranium	0/23 (0.0)	1/54 (1.85)	0/42 (0.0)	0/3 (0.0) .	1/122 (0.82)
Maxilla	0/46 (0.0)	0/79 (0.0)	0/50 (0.0)	0/4 (0.0)	0/179 (0.0)
Palate	0/29 (0.0)	0/49 (0.0)	0/46 (0.0)	0/0 (0.0)	0/124 (0.0)
Mandible	0/64 (0.0)	0/167 (0.0)	3/113 (2.66)	0/5 (0.0)	3/249 (1.21)
Ilium	0/59 (0.0)	0/117 (0.0)	2/72 (2.78)	0/2 (0.0)	2/250 (0.8)
Sacrum	0/13 (0.0)	0/59 (0.0)	0/26 (0.0)	0/1 (0.0)	0/99 (0.0)
Manubrium	0/12 (0.0)	0/25 (0.0)	0/17 (0.0)	0/0 (0.0)	0/54 (0.0)
Clavicle	0/68 (0.0)	0/175 (0.0)	2/105 (1.9)	0/9 (0.0)	2/357 (0.56)
Humerus	0/85 (0.0)	0/177 (0.0)	2/131 (1.53)	0/8 (0.0)	2/401 (0.5)
Radius	0/63 (0.0)	1/159 (0.63)	2/122 (1.64)	0/9 (0.0)	3/353 (0.85)
Ulna	0/57 (0.0)	0/148 (0.0)	3/125 (2.4)	0/9 (0.0)	3/339 (0.89)
Femur	0/90 (0.0)	0/195 (0.0)	4/110 (3.64)	1/19 (5.26)	5/435 (1.15)
Tibia	0/69 (0.0)	8/171 (4.68)	21/138 (15.22)	0/20 (0.0)	29/398 (7.29)
Fibula	0/60 (0.0)	5/141 (3.55)	8/117 (6.84)	0/16 (0.0)	13/334 (3.89)
Metacarpal	0/191 (0.0)	0/719 (0.0)	10/518 (1.93)	0/27 (0.0)	10/1455 (0.69)
Proximal hand phalanx	0/231 (0.0)	0/617 (0.0)	10/479 (2.09)	0/31 (0.0)	10/1358 (0.74)
Talus	0/42 (0.0)	0/153 (0.0)	0/126 (0.0)	0/14 (0.0)	0/335 (0.0)
Calcaneus	0/45 (0.0)	0/129 (0.0)	0/116 (0.0)	0/10 (0.0)	0/300 (0.0)
Metatarsal	0/225 (0.0)	0/717 (0.0)	11/484 (2.27)	0/95 (0.0)	11/1525 (0.72)
Proximal foot phalanx	0/131 (0.0)	0/435 (0.0)	9/338 (2.66)	0/32 (0.0)	9/936 (0.96)

Table 5.6.1 Percentage of skeletal elements with non-specific infection for pooled British samples (N/D=adult of undetermined sex).

Skeletal element	Subadults n/N (%)	Females n/N (%)	Males n/N (%)	N/D n/N (%)	Total n/N (%)
Cranium	1/27 (3.7)	1/109 (0.92)	1/90 (1.11)	1/2 (50.0)	4/228 (1.75)
Maxilla	4/63 (6.35)	0/121 (0.0)	4/117 (3.42)	0/11 (0.0)	8/312 (2.56)
Palate	2/56 (3.57)	2/84 (2.38)	4/100 (4.0)	2/8 (25.0)	10/248 (4.03)
Mandible	0/62 (0.0)	2/212 (0.94)	3/199 (1.51)	2/21 (9.52)	7/495(1.41)
Ilium	0/39 (0.0)	5/101 (4.95)	5/68 (7.35)	0/2 (0.0)	10/210 (4.76)
Sacrum	0/3 (0.0)	2/23 (8.7)	1/14 (7.14)	0/0 (0.0)	3/40 (7.5)
Manubrium	0/4 (0.0)	1/17 (5.88)	0/15 (0.0)	0/0 (0.0)	1/36 (2.78)
Clavicle	1/48 (2.08)	1/168 (0.6)	1/146 (0.69)	0/5 (0.0)	3/367 (0.82)
Humerus	0/56 (0.0)	0/189 (0.0)	2/154 (1.3)	0/15 (0.0)	2/414 (0.48)
Radius	0/29 (0.0)	0/138 (0.0)	2/116 (1.72)	0/6 (0.0)	2/289 (0.69)
Ulna	0/24 (0.0)	0/124 (0.0)	4/109 (3.67)	0/7 (0.0)	4/264 (1.52)
Femur	1/72 (1.39)	2/217 (0.92)	5/170 (2.94)	0/18 (0.0)	8/477 (1.68)
Tibia	0/61 (0.0)	23/194 (11.86)	37/167 (22.16)	2/10 (20.0)	62/432 (14.35)
Fibula	0/31 (0.0)	4/105 (3.81)	22/96 (22.92)	0/5 (0.0)	26/237 (10.97)
Metacarpal	0/60 (0.0)	0/484 (0.0)	2/386 (0.52)	0/26 (0.0)	2/956 (0.21)
Proximal hand phalanx	0/48 (0.0)	0/368 (0.0)	0/307 (0.0)	0/22 (0.0)	0/745 (0.0)
Talus	0/24 (0.0)	1/158 (0.63)	1/132 (0.76)	0/18 (0.0)	2/332 (0.6)
Calcaneus	0/19 (0.0)	0/117 (0.0)	5/109 (4.59)	0/16 (0.0)	5/261 (1.92)
Metatarsal	0/100 (0.0)	0/809 (0.0)	3/625 (0.48)	0/72 (0.0)	3/1606 (0.19)
Proximal foot phalanx	0/21 (0.0)	0/217 (0.0)	1/159 (0.63)	0/14 (0.0)	1/411 (0.24)

Table 5.6.2 Percentage of skeletal elements with non-specific infection for pooled German samples (N/D=adult of undetermined sex).

Skeletal element	Subadults n/N (%)	Females n/N (%)	Males n/N (%)	N/D n/N (%)	Total n/N (%)
Cranium	0/23 (0.0)	1/54 (1.85)	0/42 (0.0)	0/3 (0.0)	1/122 (0.82)
Maxilla	0/20 (0.0)	0/35 (0.0)	0/20 (0.0)	0/2 (0.0)	0/77 (0.0)
Palate	0/14 (0.0)	0/21 (0.0)	0/21 (0.0)	0/0 (0.0)	0/56 (0.0)
Mandible	0/26 (0.0)	0/71 (0.0)	2/50 (4.0)	0/2 (0.0)	2/149 (1.34)
Ilium	0/25 (0.0)	0/45 (0.0)	1/29 (3.45)	0/1 (0.0)	1/100 (1.0)
Sacrum	0/13 (0.0)	0/59 (0.0)	0/26 (0.0)	0/1 (0.0)	0/99 (0.0)
Manubrium	0/12 (0.0)	0/25 (0.0)	0/17 (0.0)	0/0 (0.0)	0/54 (0.0)
Clavicle	0/25 (0.0)	0/74 (0.0)	1/44 (2.27)	0/3 (0.0)	1/146 (0.69)
Humerus	0/34 (0.0)	0/69 (0.0)	1/56 (1.79)	0/2 (0.0)	1/161 (0.62)
Radius	0/22 (0.0)	1/60 (1.67)	1/54 (1.85)	0/4 (0.0)	2/140 (1.43)
Ulna	0/21 (0.0)	0/54 (0.0)	2/51 (3.92)	0/1 (0.0)	2/127 (1.58)
Femur	0/43 (0.0)	0/85 (0.0)	3/58 (5.17)	1/7 (14.29)	4/193 (2.07)
Tibia	0/34 (0.0)	6/73 (8.22)	15/64 (23.44)	0/7 (0.0)	21/178 (11.8)
Fibula	0/25 (0.0)	4/60 (6.67)	5/51 (9.8)	0/5 (0.0)	9/141 (6.38)
Metacarpal	0/11 (0.0)	0/34 (0.0)	1/31 (3.23)	0/1 (0.0)	1/77 (1.3)
Proximal hand phalanx	0/9 (0.0)	0/25 (0.0)	1/22 (4.55)	0/1 (0.0)	1/57 (1.75)
Talus	0/15 (0.0)	0/56 (0.0)	0/52 (0.0)	0/4 (0.0)	0/127 (0.0)
Calcaneus	0/13 (0.0)	0/42 (0.0)	0/46 (0.0)	0/4 (0.0)	0/97 (0.0)
Metatarsal	0/13 (0.0)	0/42 (0.0)	2/37 (5.41)	0/4 (0.0)	2/96 (2.08)
Proximal foot phalanx	0/1 (0.0)	0/20 (0.0)	1/15 (6.67)	0/0 (0.0)	1/36 (2.78)

Table 5.6.3 Percentage of individuals with non-specific infection by skeletal element for pooled British samples (N/D=adult of undetermined sex).

Skeletal element	Subadults n/N (%)	Females n/N (%)	Males n/N (%)	N/D n/N (%)	Total n/N (%)
Cranium	1/27 (3.7)	1/109 (0.92)	1/90 (1.11)	1/2 (50.0)	4/228 (1.75)
Maxilla	2/25 (8.0)	0/50 (0.0)	3/48 (6.25)	0/3 (0.0)	5/127 (3.93)
Palate	1/26 (3.85)	1/40 (2.5)	2/46 (4.35)	1/3 (33.33)	5/113 (4.43)
Mandible	0/26 (0.0)	2/89 (2.25)	3/88 (3.41)	1/8 (12.5)	6/211 (2.84)
Ilium	0/15 (0.0)	3/40 (7.5)	3/30 (10.0)	0/1 (0.0)	6/86 (6.98)
Sacrum	0/3 (0.0)	2/23 (8.7)	1/14 (7.14)	0/0 (0.0)	3/40 (7.5)
Manubrium	0/4 (0.0)	1/17 (5.88)	0/15 (0.0)	0/0 (0.0)	1/36 (2.78)
Clavicle	1/19 (5.26)	1/70 (1.43)	1/63 (1.59)	0/2 (0.0)	3/154 (1.95)
Humerus	0/23 (0.0)	0/78 (0.0)	2/65 (3.08)	0/3 (0.0)	2/169 (1.18)
Radius	0/11 (0.0)	0/48 (0.0)	2/41 (4.88)	0/1 (0.0)	2/101 (1.98)
Ulna	0/9 (0.0)	0/39 (0.0)	3/37 (8.11)	0/2 (0.0)	3/87 (3.45)
Femur	1/30 (3.33)	2/96 (2.08)	4/71 (5.63)	0/6 (0.0)	7/203 (3.45)
Tibia	0/24 (0.0)	18/86 (20.93)	28/77 (36.36)	2/5 (40.0)	48/193(24.87)
Fibula	0/11 (0.0)	3/30 (10.0)	16/40 (40.0)	0/2 (0.0)	19/83 (22.89)
Metacarpal	0/1 (0.0)	0/3 (0.0)	1/6 (16.67)	0/0 (0.0)	1/10 (10.0)
Proximal hand phalanx	0/8 (0.0)	0/2 (0.0)	0/3 (0.0)	0/0 (0.0)	0/5 (0.0)
Talus	0/9 (0.0)	1/61 (1.64)	1/63 (1.59)	0/7 (0.0)	2/130 (1.54)
Calcaneus	0/7 (0.0)	0/48 (0.0)	3/47 (6.38)	0/6 (0.0)	3/108 (2.78)
Metatarsal	0/4 (0.0)	0/25 (0.0)	3/31 (9.68)	0/0 (0.0)	3/60 (5.0)
Proximal foot phalanx	0/0 (0.0)	0/0 (0.0)	1/1 (100.0)	0/0 (0.0)	1/1 (100.0)

Table 5.6.4 Percentage of individuals with non-specific infection by skeletal element for pooled German samples (N/D=adult of undetermined sex).

Having German males identified as the sub-sample most at risk of non-specific infection, the age group at the highest risk had to be established as well. It is obvious that remodelled, and therefore healed, lesions could have been sustained at any point during a person's life. For this reason lesions displaying active new bone formation and lesions of a mixed nature with both remodelled and woven new bone formation indicative of a recurring insult were analysed. This analysis can be conducted in two ways: firstly, the number of individuals with active lesions in each age class can be expressed as a proportion of all individuals in each age category or, secondly, the number of skeletons with active lesions can be expressed in relation to the number of all individuals with lesions in each age class. The latter approach was favoured here, because of the variability in preservation of skeletal remains. For the pooled British samples, almost one third of all adults (30.76 percent) displayed unhealed lesions. A total of 36 active bone changes (46.15 percent) were observed for the combined German samples. Compared to unhealed British lesions this difference was statistically not significant (χ^2=1.8909, p=0.1691, d.f.=1). Because of the low number of unhealed lesions in the British samples, the result for each age category was combined for both sexes (Table 5.6.5). The discrepancy in numbers between individuals with active new bone formation in the German sample (n=36) and the number of individuals in all

German age categories (n=33) is due to the fact that three German adults were of undetermined age. Although none of the British samples had non-adult involvement, the young adult age category displayed the highest proportion of active lesions with three-quarters of all individuals affected. The chance of exhibiting active lesions dropped considerably in the next age class (8.33 percent), but rose again sharply in the middle-age category (66.67 percent), while individuals over the age of 45 years had reduced rates (20.0 percent). Unhealed new bone formation was most prevalent in the German non-adults and young adults (66.67 percent and 75.0 percent, respectively), while all other age categories had experienced a decrease in active lesions (40.91 percent and 33.33 percent, respectively). However, an increase in numbers was observed for old adults (46.67 percent).

Age category	<16 n/N (%)	16-25 n/N (%)	26-35 n/N (%)	36-45 n/N (%)	45+ n/N (%)
Total GB	0/0 (0.0)	3/4 (75.0)	1/12 (8.33)	2/3 (66.67)	2/10 (20.0)
Total D	4/6 (66.67)	6/8 (75.0)	9/22 (40.91)	7/21 (33.33)	7/15 (46.67)

Table 5.6.5 Percentage of active new bone formation as a proportion of all individuals with any type of new bone formation by age class (n=number of individuals with active lesions, N=number if individuals with new bone formation, total GB=pooled British samples, total D=pooled German samples).

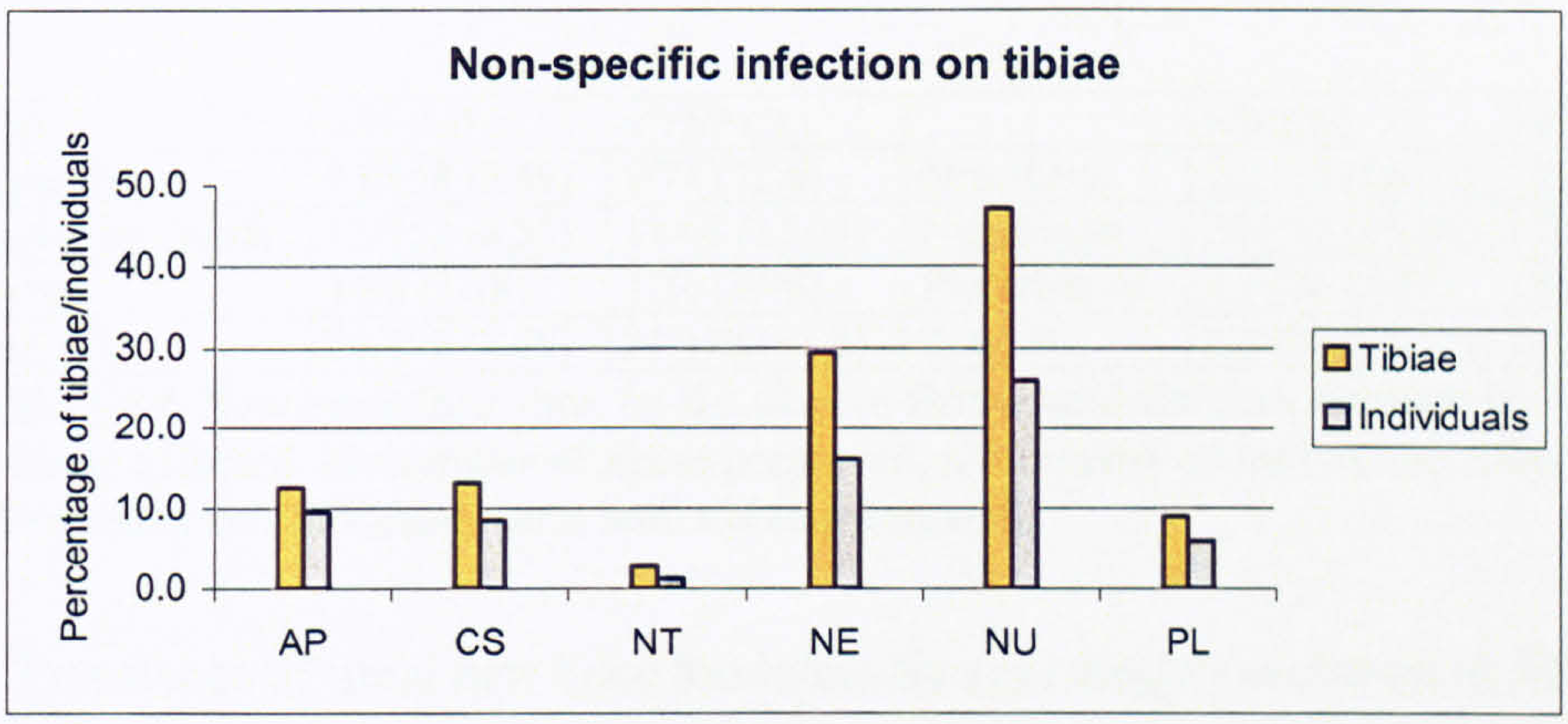


Fig. 5.6.1 Prevalence of non-specific infections on tibiae by number of tibiae preserved (Tibiae) and by individual count (Individuals) (AP=Apple Down, CS=Castledyke South, NT=Norton, NE=Neresheim, NU=Nusplingen, PL=Pleidelsheim).

The predominance of tibial new bone formation in the study samples warranted a more detailed analysis of this phenomenon. A comparison of tibial reactive new bone formation by number of tibiae as well as by number of individuals affected is presented in Fig. 5.6.1. Frequencies for each individual site are tabulated in Table 5.6.6 for both bone count and individual count.

All three British samples experienced low rates of tibial new bone formation with frequencies ranging from as low as 1.18 percent at Norton, 8.55 percent at Castledyke South to as high as 9.49 percent at Apple Down when concentrating on the number of tibiae preserved. Only one of the German samples had a comparatively low frequency rate, 5.91 percent were observed at Pleidelsheim, while the other two displayed a much higher prevalence with 16.15 percent at Neresheim and 25.86 percent at Nusplingen. Taking into account all individuals with both tibiae observable, Norton still showed the lowest prevalence (2.78 percent), while individuals from Castledyke South experienced the highest rates within the British samples (13.24 percent), shortly followed by Apple Down (12.6 percent). Among the German samples, Pleidelsheim, again, was at the lower end of the scale with 8.99 percent, while at Neresheim almost one-third of individuals (29.41 percent) had new bone formed on their tibiae, and at Nusplingen nearly half of all skeletons (47.17 percent) had lesions on the tibiae. While the difference between the British samples was not of a magnitude to be statistically significant (χ^2=4.0771, p=0.1302, d.f.=2), differences between the three German sites were large enough (χ^2=26.5993, p=0.0000, d.f.=2) to be of a statistically significant value.

Tibia	n/N (%)	n*/N* (%)		n/N (%)	n*/N* (%)
Apple Down	15/158 (9.49)	9/74 (12.6)	Neresheim	21/130 (16.15)	15/51 (29.41)
Castledyke South	13/152 (8.55)	11/68 (13.24)	Nusplingen	30/116 (25.86)	25/53 (47.17)
Norton	1/88 (1.18)	1/36 (2.78)	Pleidelsheim	11/186 (5.91)	8/89 (8.99)
Total GB	29/398 (7.29)	21/178 (11.8)	Total D	62/432 (14.35)	48/193 (24.87)

Table 5.6.6 New bone formation on the tibia in British and German samples by site (n=number of tibiae affected, N=number of tibiae preserved, n*=number of individuals affected, N*=number of individuals with both tibiae preserved).

Prevalence of tibial new bone formation by age category is shown in Table 5.6.7 and Fig. 5.6.2. None of the British or German non-adults had any changes observable on their tibiae. For the combined British samples, an increase with advancing age is interrupted only in the middle-age category, where almost the same low frequency as in the young adult age class was reached. However, old adults displayed a sharp increase in new bone formation on this skeletal element. A similar trend was observed in the pooled German samples; again, old adults had the highest rates with half of all individuals affected. Prevalence dropped in the middle-age category after an initial rise in young adults. Differences in both countries were statistically significant between younger (<16-35 years) and older (36-45+ years) individuals (British samples: χ^2=4.6793, p=0.0305, d.f.=1; German samples: χ^2=9.5473, p=0.0020, d.f.=1).

Age category	GB n/N (%)	D n/N (%)
<16	0/34 (0.0)	0/24 (0.0)
16-25	2/28 (7.14)	5/19 (26.23)
26-35	7/53 (13.21)	11/63 (17.46)
36-45	3/39 (7.69)	14/48 (29.47)
45+	8/19 (42.11)	10/20 (50.0)
Adult	1/5 (20.0)	8/19 (42.11)
Total	21/178 (11.8)	48/193 (24.87)

Table 5.6.7 Prevalence of non-specific infection on tibiae by age category and country – individual count (GB=pooled British samples, D=pooled German samples, n=number of individuals affected, N=number of individuals present).

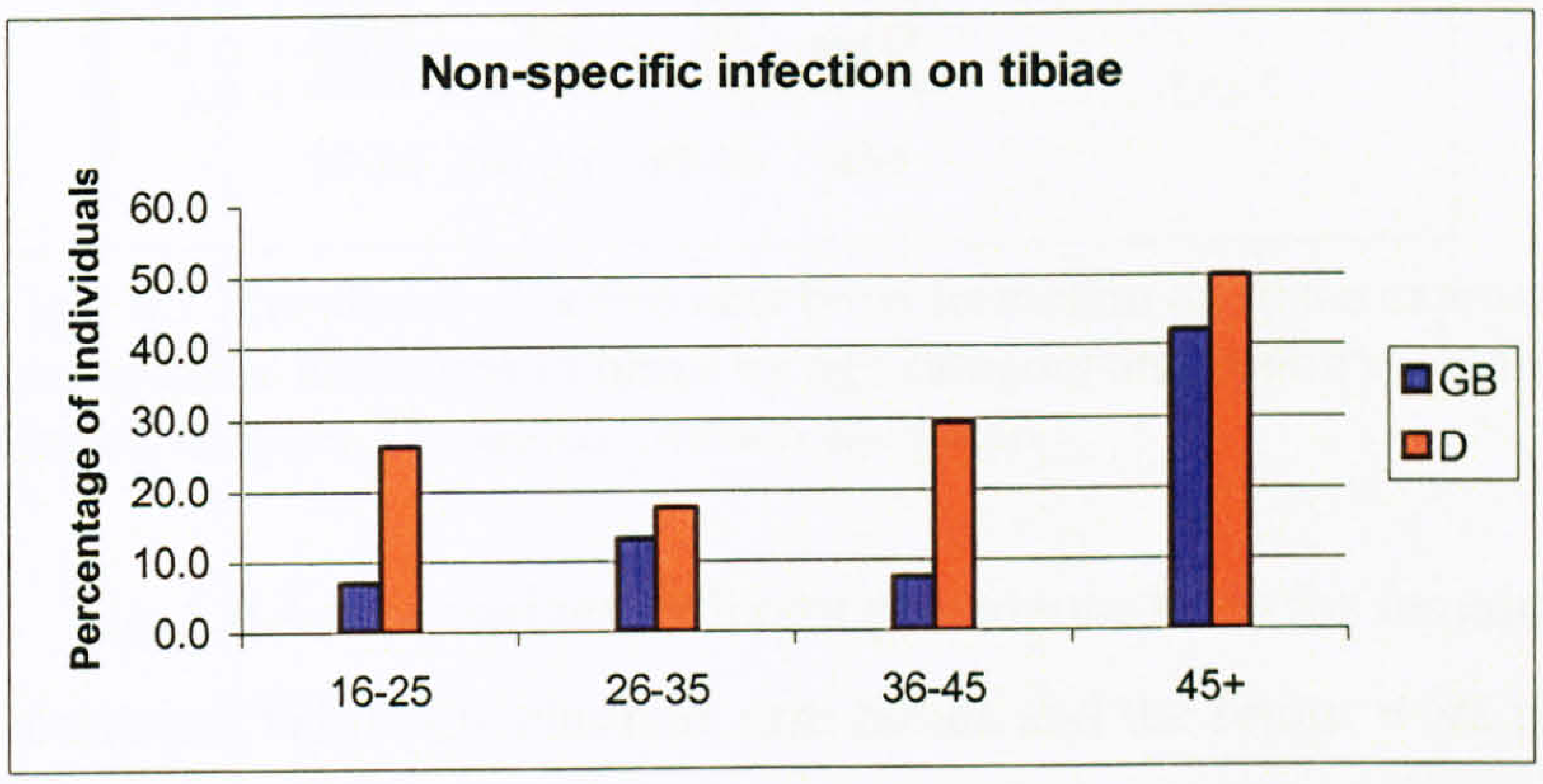


Fig. 5.6.2 Prevalence of non-specific infection on tibiae by age categories and country – individual count (GB=pooled British samples, D=pooled German samples).

Age category	GB n/N (%)	D n/N (%)
<16	0/0 (0.0)	0/0 (0.0)
16-25	1/2 (50.0)	4/5 (80.0)
26-35	0/7 (0.0)	3/11 (27.27)
36-45	0/3 (0.0)	3/14 (21.43)
45+	1/8 (12.5)	3/10 (30.0)
Adult	0/1 (0.0)	2/8 (25.0)
Total	2/21 (9.52)	15/48 (31.25)

Table 5.6.8 Prevalence of active new bone formation on tibiae expressed as a percentage of all non-specific infections of tibiae by age category and country – individual count (GB=pooled British samples, D=pooled German samples, n=number of individuals affected, N=number of individuals observed).

To explore further trends, active new bone formation prevalence on the tibiae was tabulated by age category and this data is presented in Table 5.6.8 and Fig. 5.6.3. Clearly, the pooled German samples showed a higher prevalence of unhealed lesions with almost one-third (31.25 percent) of individuals having active bone changes when they died. British individuals had comparatively few unhealed lesions (9.52 percent). The highest prevalence (80.0 percent) was found in young adults from the German sites, while British skeletons had one individual affected in the young and old adult category. However, this difference between the two pooled samples could not be tested for statistical significance because of the low number of British individuals with active lesions.

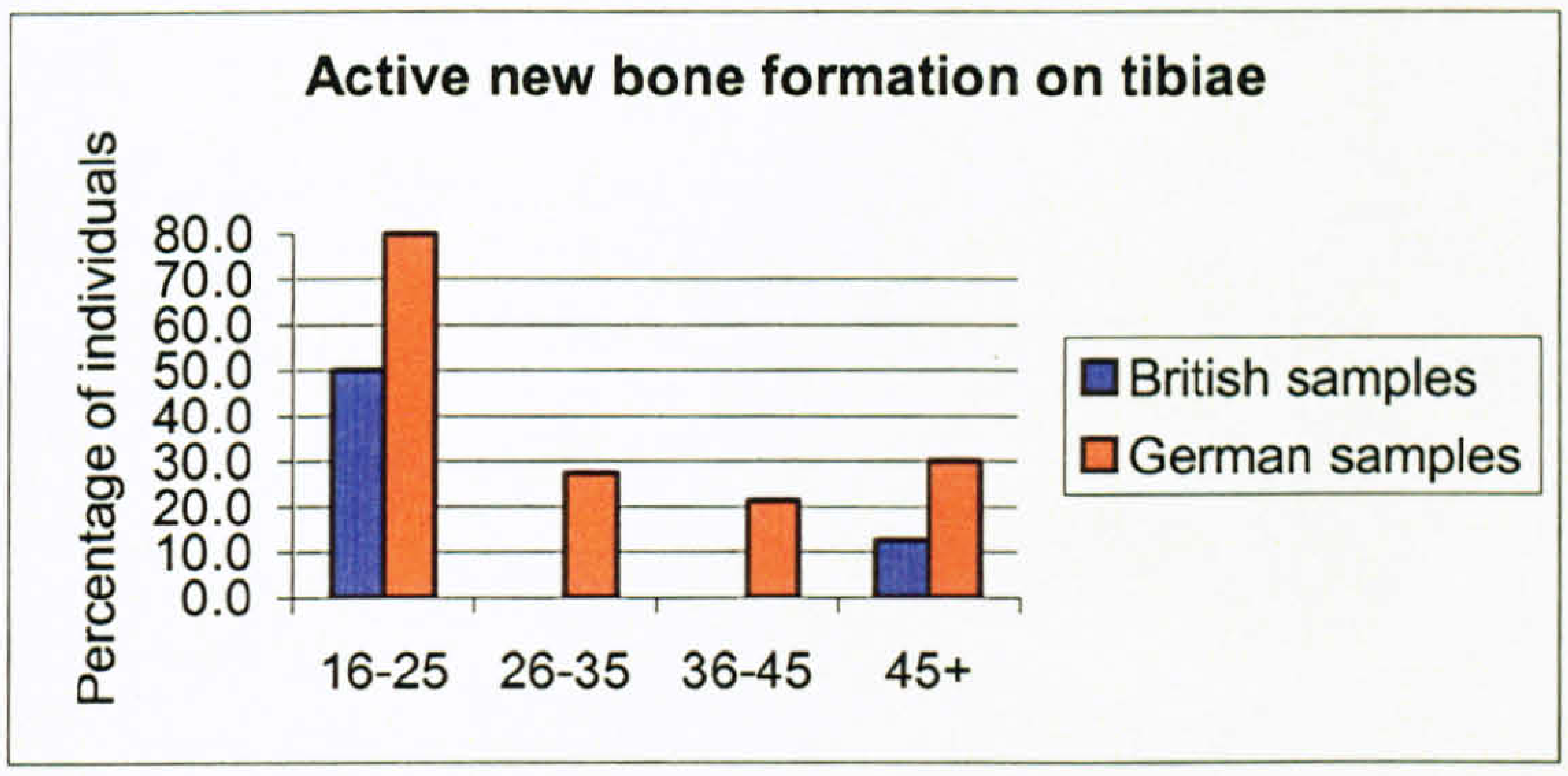


Fig 5.6.3 Prevalence of active new bone formation on tibiae expressed as a percentage of all non-specific infections of tibiae by age category and country – individual count (GB=pooled British samples, D=pooled German samples).

Fig. 5.6.4 summarizes different prevalence rates for females and males from both countries. While the clavicle, arm bones and the femur were rarely affected, frequencies were higher for the tibiae and fibulae, especially in German males. The fibula and to a slightly lesser extent the tibia were also the bones most often fractured in the male sub-sample (see 5.5.1 Postcranial fractures) and injuries not severe enough to induce a fracture could have been responsible for at least some of the observed periosteal reactions. However, the clavicle, which was most often fractured in British males, did not display elevated rates of periosteal reaction.

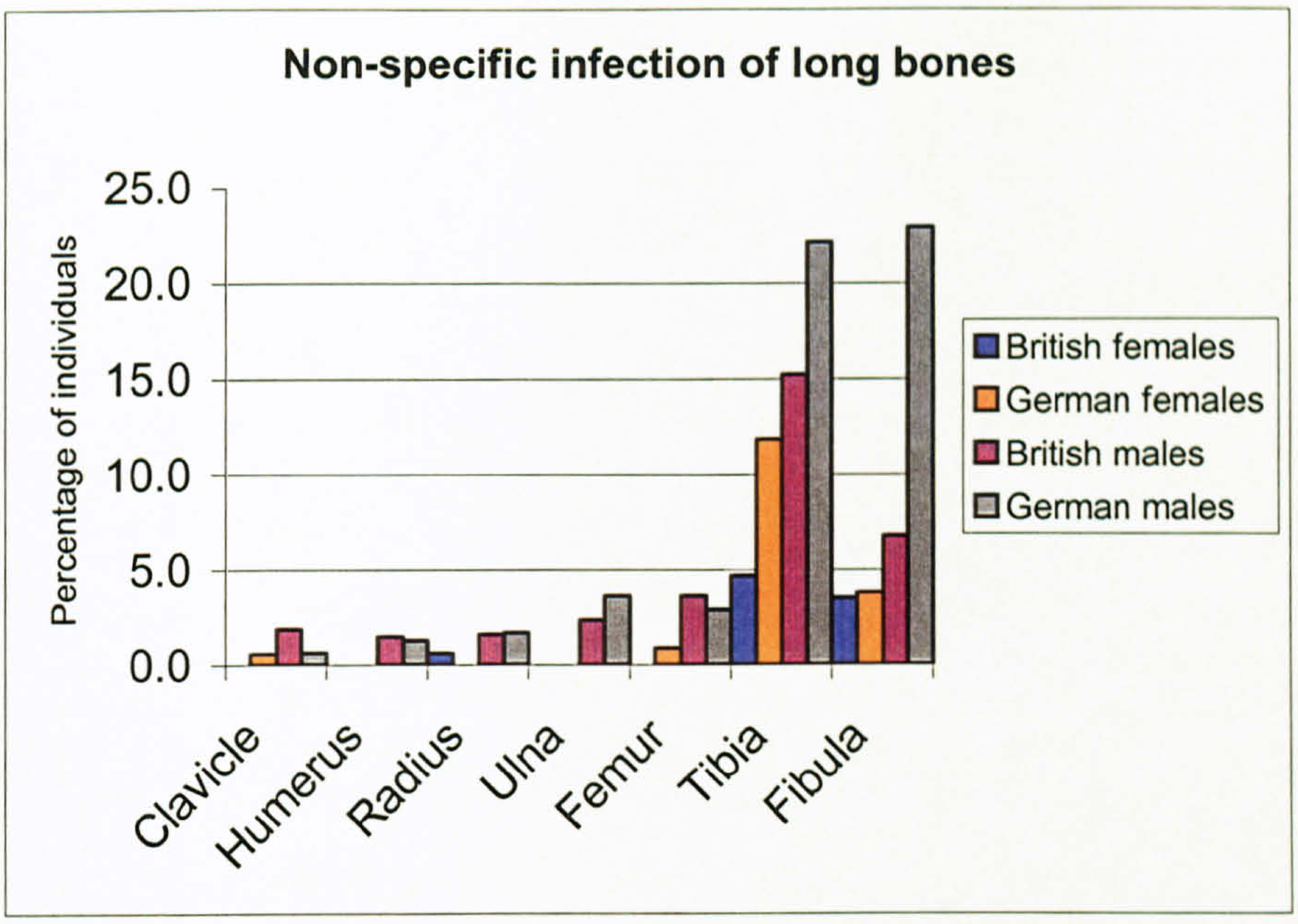


Fig. 5.6.4 Prevalence of non-specific infection on long bone by sex and country – individual count.

5.6.2 Chronic maxillary sinusitis

Tables 5.6.9-5.6.13 and Fig. 5.6.5 present data for maxillary sinusitis by number of sinuses affected as well as by number of individuals with sinuses present for analysis. Separate tables were produced for non-adults, females, males, adults of undetermined sex and overall prevalence for each of the pooled samples. More information on each individual with maxillary sinusitis can be found in Appendix C6, Tables 7-12. Since there was no statistically significant difference in the combined British and German samples between left and right side involvement, both sinuses were combined (British samples: χ^2=2.6776, p=0.1018, d.f.=1; German samples: χ^2=0.3026, p=0.5823, d.f.=1).

Maxillary sinusitis prevalence was low in non-adults (Table 5.6.9). Only one sinus from the British site of Apple Down displayed new bone formation (2.5 percent); consequently, rates for individuals were similarly low (6.67 percent). German non-adults had suffered bony changes consistent with chronic maxillary sinusitis at the sites of Neresheim (9.38 percent) and Nusplingen (12.5 percent) affecting 5 of 77 sinuses in total (6.49 percent). However, on an individual basis, only three of 30 non-adults (9.09 percent) were involved.

Site	n/N (%)	n*/N* (%)	Site	n/N (%)	n*/N* (%)
Apple Down	1/27 (3.7)	1/12 (8.33)	Neresheim	3/32 (9.38)	2/13 (15.39)
Castledyke South	0/11 (0.0)	0/2 (0.0)	Nusplingen	2/16 (12.5)	1/4 (25.0)
Norton	0/2 (0.0)	0/1 (0.0)	Pleidelsheim	0/29 (0.0)	0/13 (0.0)
Total GB	1/40 (2.5)	1/15 (6.67)	Total D	5/77 (6.49)	3/30 (9.09)

Table 5.6.9 Non-adult maxillary sinusitis in British and German samples by bone and individual count (n=number of sinuses affected, N=number of sinuses preserved, n*=number of individuals affected, N*=number of individuals with both sinuses preserved).

Females from all six study samples showed varying frequencies of chronic maxillary sinusitis (Table 5.6.10). Prevalence was low at Castledyke South (6.67 percent of maxillary sinuses and 16.67 percent of female individuals). Almost one-third (32.0 percent) of sinuses attributed to females from Norton were affected, while on an individual level nearly half of all females (45.46 percent) from this site had suffered changes to their sinuses. At Apple Down, prevalence for sinusitis was 20.0 percent, or slightly more than one-third of all female skeletons (34.62 per cent). Prevalence of maxillary sinusitis was high for all German sites with Nusplingen having the lowest rates for both – skeletal elements and individuals affected (21.43 percent of sinuses and 39.13 percent of female skeletons). At Pleidelsheim, maxillary sinusitis prevalence was higher (28.57 percent of sinuses and 44.44 percent of female skeletons). At Neresheim, nearly one-third of all observable sinuses showed new bone formation (32.1 percent) and half of all females exhibited bony changes.

Site	n/N (%)	n*/N* (%)	Site	n/N (%)	n*/N* (%)
Apple Down	11/55 (20.0)	9/26 (34.62)	Neresheim	26/81 (32.1)	18/36 (50.0)
Castledyke South	2/30 (6.67)	2/12 (16.67)	Nusplingen	12/56 (21.43)	9/23 (39.13)
Norton	8/25 (32.0)	5/11 (45.46)	Pleidelsheim	16/56 (28.57)	12/27 (44.44)
Total GB	21/110 (19.09)	16/49 (32.65)	Total D	54/193 (27.98)	39/86 (45.3)

Table 5.6.10 Female maxillary sinusitis in British and German samples by bone and individual count (n=number of sinuses affected, N=number of sinuses preserved, n*=number of individuals affected, N*=number of individuals with both sinuses preserved).

Male prevalence of maxillary sinusitis can be assessed in Table 5.6.11. Males from Castledyke South had experienced similar low rates as their female counterparts (7.24 percent of sinuses and 18.18 percent of male skeletons). At Apple Down, prevalence was higher compared to males from Castledyke South (12.77 percent of sinuses and 21.74 percent of male skeletons). The highest male frequency was found at Norton, where one-third of male sinuses or half of all male individuals had new bone formation on the internal surface of their sinuses. Among the German sites, males from Pleidelsheim had relatively low rates (13.79 percent of sinuses and 20.0 percent of male skeletons). One-fourth of all male individuals from Nusplingen had suffered from chronic maxillary sinus inflammation affecting 16.67 percent of all observable male sinuses. At Neresheim, male sinusitis prevalence was highest with 29.31 percent of all sinuses affected, or 44.44 percent of all male individuals.

Site	n/N (%)	n*/N* (%)	Site	n/N (%)	n*/N* (%)
Apple Down	6/47 (12.77)	5/23 (21.74)	Neresheim	17/58 (29.31)	12/27 (44.44)
Castledyke South	2/28 (7.14)	2/11 (18.18)	Nusplingen	14/84 (16.67)	10/40 (25.0)
Norton	4/12 (33.33)	3/6 (50.0)	Pleidelsheim	4/33 (13.79)	3/15 (20.0)
Total GB	12/87 (13.79)	10/40 (25.0)	Total D	35/175 (20.0)	25/82 (30.49)

Table 5.6.11 Male maxillary sinusitis in British and German samples by bone and individual count (n=number of sinuses affected, N=number of sinuses preserved, n*=number of individuals affected, N*=number of individuals with both sinuses preserved).

Prevalence of maxillary sinusitis for adults of undetermined sex is tabulated in Table 5.6.12. None of the two unsexed British adults were affected. However, at Nusplingen more than one-third of sinuses belonging to unsexed adults (34.78 percent), or 70.0 percent of individuals had new bone formation on the internal surface of their maxillary sinuses.

Site	n/N (%)	n*/N* (%)	Site	n/N (%)	n*/N* (%)
Apple Down	0/2 (0.0)	0/1 (0.0)	Neresheim	0/3 (0.0)	0/1 (0.0)
Castledyke South	0/0 (0.0)	0/0 (0.0)	Nusplingen	8/23 (34.78)	7/10 (70.0)
Norton	0/3 (0.0)	0/1 (0.0)	Pleidelsheim	0/0 (0.0)	0/0 (0.0)
Total GB	0/5 (0.0)	0/2 (0.0)	Total D	8/26 (30.77)	7/11 (63.64)

Table 5.6.12 Unsexed adult maxillary sinusitis in British and German samples by bone and individual count (n=number of sinuses affected, N=number of sinuses preserved, n*=number of individuals affected, N*=number of individuals with both sinuses preserved).

Overall frequencies for each site by bone and individual count can be found in Table 5.6.13 and Fig. 5.6.5. When comparing maxillary sinusitis prevalence between the pooled British and German samples, individuals from the German cemeteries just missed having statistically significantly higher rates of chronic maxillary sinusitis (χ^2=3.1869, p=0.0742, d.f.=1). Although British females had more maxillary sinusitis than their male counterparts, this difference did not prove to be of statistically significant proportions (χ^2=0.6237, p=0.4297, d.f.=1). The contrary was observed when prevalence rates between German females and males were compared. Here, differences were statistically significant (χ^2=3.9310, p=0.0474, d.f.=1), with females having higher rates. A statistical test of maxillary sinusitis prevalence between sites within the two countries turned out to be statistically insignificant (British samples: χ^2=4.0039, p=0.1351, d.f.=2; German samples: χ^2=2.8691, p=0.2382, d.f.=2). Similarly, comparing differences between the sexes across the two countries did not yield values high enough to be of statistical significance (British and German females: (χ^2=2.0840, p=0.1489, d.f.=1; British and German males: (χ^2=0.3958, p=0.5293, d.f.=1).

Site	n/N (%)	n*/N* (%)	Site	n/N (%)	n*/N* (%)
Apple Down	18/131 (13.74)	15/62 (24.19)	Neresheim	46/174 (26.44)	32/77 (41.56)
Castledyke South	4/69 (5.8)	4/25 (16.0)	Nusplingen	36/179 (30.11)	27/77 (35.07)
Norton	12/42 (28.57)	8/19 (42.11)	Pleidelsheim	20/118 (16.95)	15/55 (27.27)
Total GB	34/242 (14.05)	27/106 (25.47)	Total D	102/471 (21.66)	74/209 (35.41)

Table 5.6.13 Total maxillary sinusitis in British and German samples by bone and individual count (n=number of sinuses affected, N=number of sinuses preserved, n*=number of individuals affected, N*=number of individuals with both sinuses preserved).

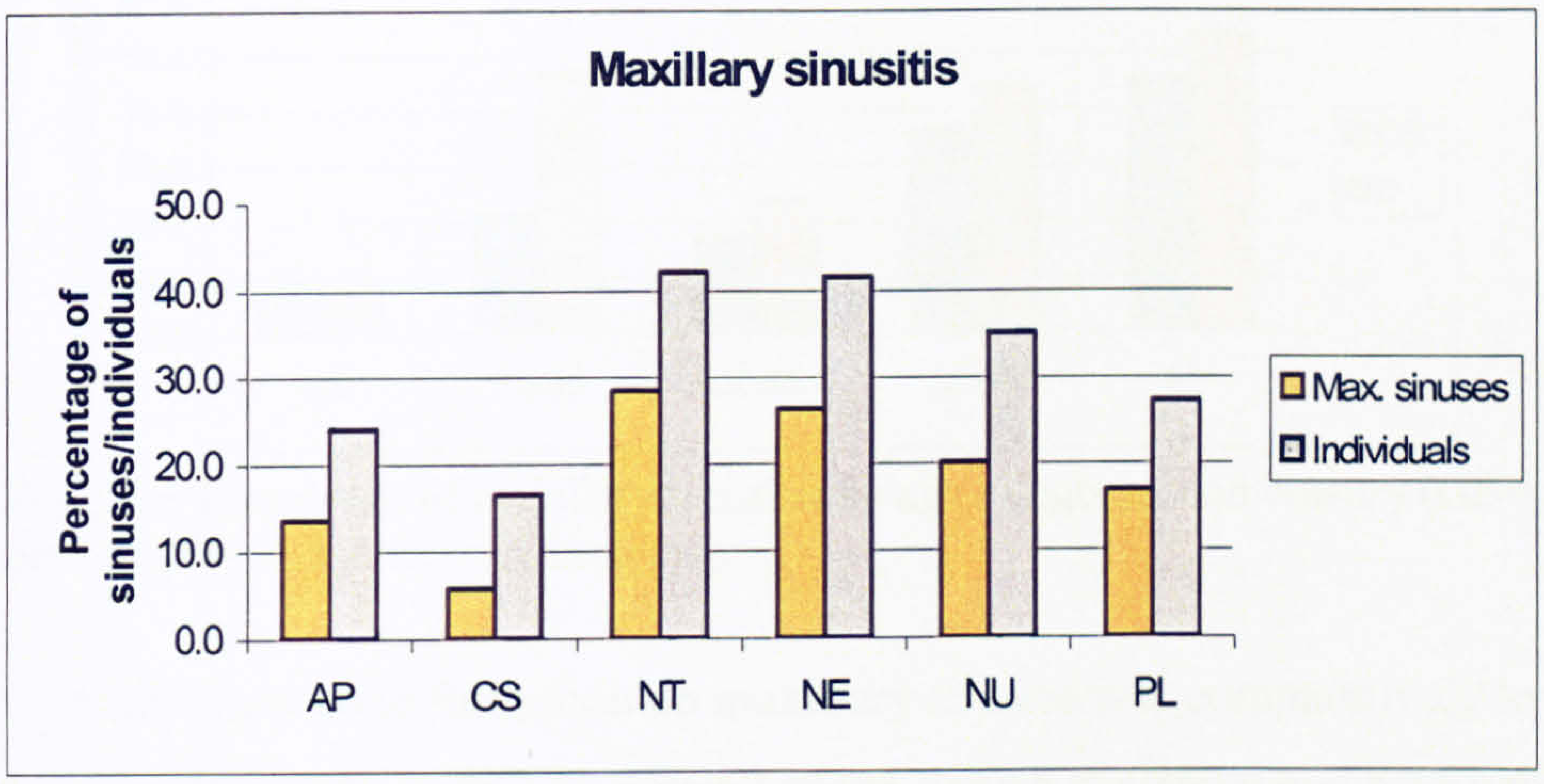


Fig. 5.6.5 Prevalence of maxillary sinusitis by total number of maxillary sinuses preserved (Max. sinuses) and individual count (Individuals) (AP=Apple Down, CS=Castledyke South, NT=Norton, NE=Neresheim, NU=Nusplingen, PL=Pleidelsheim).

Table 5.6.14 and Fig. 5.6.6 display the prevalence of maxillary sinusitis by individual age category for both pooled samples. For the British sites, a steady increase in prevalence with advancing age is observed, although individuals in the young adult category had slightly more maxillary sinusitis (21.43 percent) than individuals in the next age class (17.14 percent). A similar increase was seen for the German samples. However, in the young adult category, individuals were experiencing a peak in prevalence rates with almost half of them displaying evidence of chronic maxillary sinusitis (47.83 percent). Chi-squared tests were performed to establish whether the observed differences between younger (<16-35 years) and older (36-45+ years) individuals with maxillary sinusitis were significant and this, indeed, proved to be the case (British samples: χ^2=7.3444, p=0.0067, d.f.=1; German samples: χ^2=8.9903, p=0.0027, d.f.=1)

Age category	GB n/N (%)	D n/N (%)
<16	1/15 (6.67)	3/30 (10.0)
16-25	3/14 (21.43)	11/23 (47.83)
26-35	6/35 (17.14)	17/71 (23.94)
36-45	11/30 (36.67)	25/57 (43.86)
45+	5/11 (45.46)	8/15 (53.33)
Adult	1/1 (100.0)	10/13 (76.92)
Total	27/106 (7.41)	74/209 (35.41)

Table 5.6.14 Prevalence of maxillary sinusitis by age category and country – individual count (GB=pooled British samples, D=pooled German samples, n=number of individual affected, N=number of individuals observable).

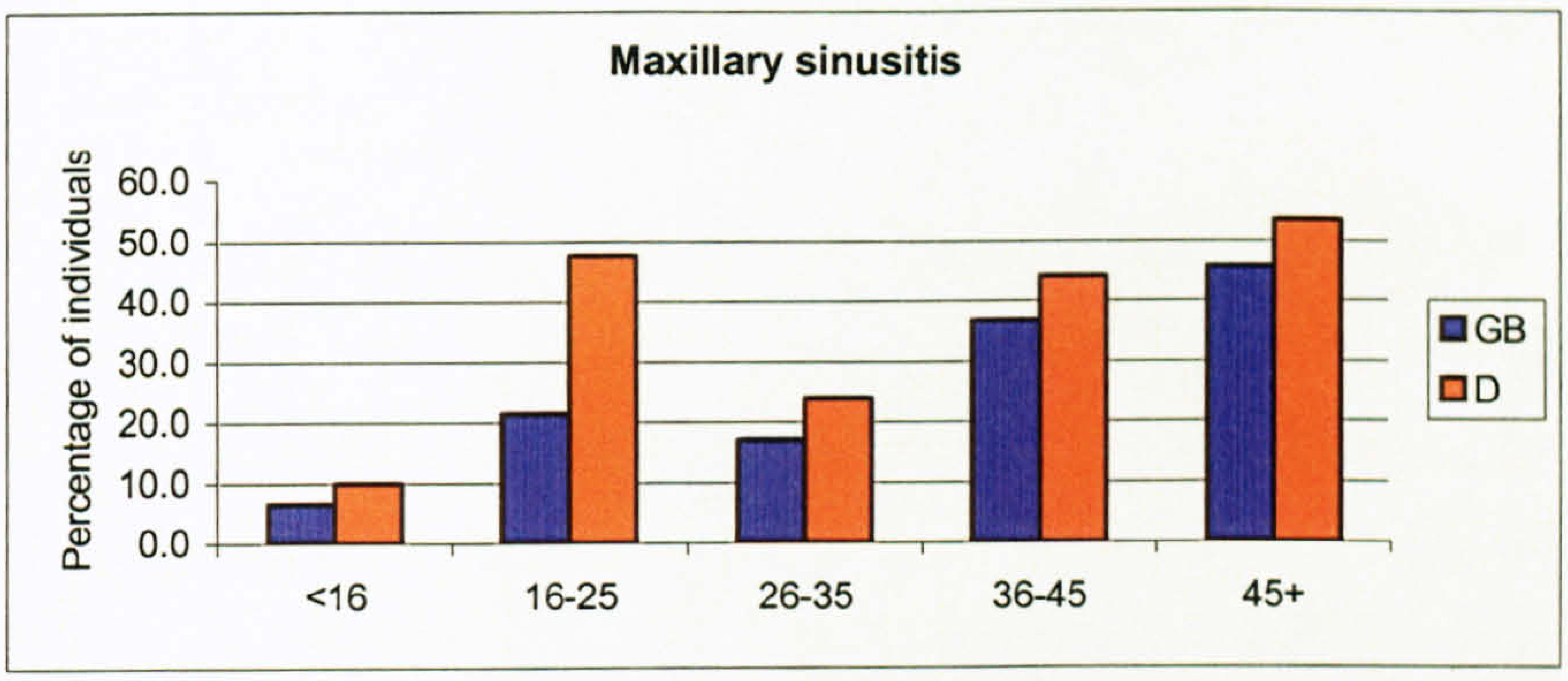


Fig. 5.6.6 Prevalence of maxillary sinusitis by age categories and country (GB=pooled British samples, D=pooled German samples).

Active new bone formation on maxillary sinuses was comparatively low in both combined samples with 7.41 percent of the British skeletons and 8.11 percent of the German skeletons showing woven new bone formation (Table 5.6.15). Within the British sites, only middle-aged individuals were affected, while in the German samples the highest prevalence (33.33 percent) was seen in the non-adult part of the population (Fig. 5.6.7). No statistical test was performed, as the number of affected individuals was low.

Age category	GB n/N (%)	D n/N (%)
<16	0/1 (0.0)	1/3 (33.33)
16-25	0/3 (0.0)	2/11 (18.18)
26-35	0/6 (0.0)	1/17 (5.88)
36-45	2/11 (18.18)	2/25 (8.0)
45+	0/5 (0.0)	0/7 (0.0)
Adult	0/1 (0.0)	0/10 (0.0)
Total	2/27 (7.41)	6/74 (8.11)

Table 5.6.15 Prevalence of active maxillary sinusitis expressed as a percentage of all maxillary sinus changes by age category and country – individual count (GB=pooled British samples, D=pooled German samples, n=number of individual affected, N=number of individuals observable).

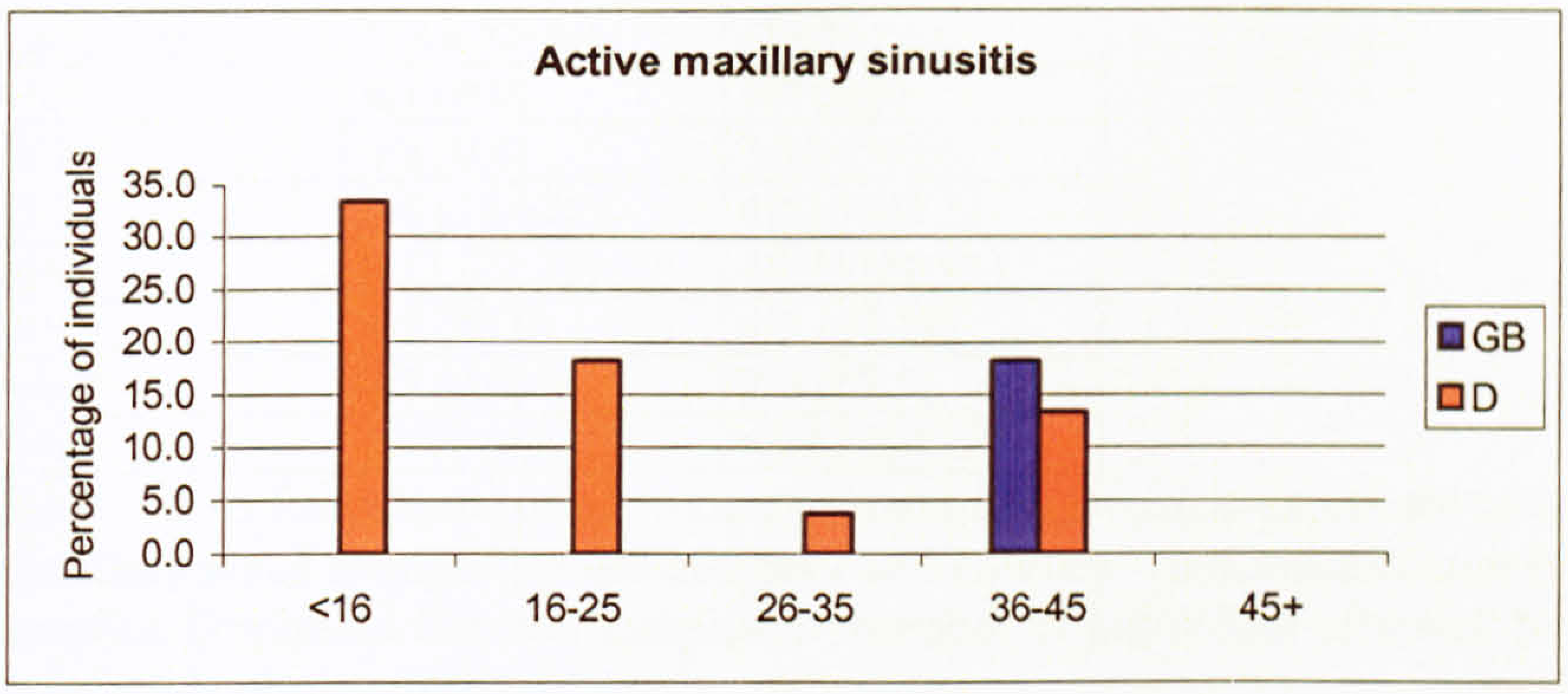


Fig. 5.6.7 Prevalence of active maxillary sinusitis expressed as a percentage of all maxillary sinus changes by age category and country – individual count (GB=pooled British samples, D=pooled German samples).

To account for one of the causative factors of maxillary sinusitis – dental inflammation in the form of abscesses, severe tooth destruction by dental caries, pulp exposure and ante-mortem tooth loss – all individuals with maxillary sinusitis and their corresponding portion of the maxilla available for study were tabulated in Table 5.6.16. Seven German individuals did not have the necessary part of their maxillae preserved and for this reason the number of individuals was slightly lower (67 instead of the 74 individuals with maxillary sinusitis). Prevalence of maxillary sinusitis induced by dental inflammation was higher in the combined German samples (64.18 percent) than the British samples, where almost half of all individuals displayed odontogenic maxillary sinusitis (48.15 percent). However, chi-squared testing did not reveal a statistically significant difference between the two countries (χ^2=2.0536, p=0.1519, d-f.=1). Subadults did not suffer any dentally induced maxillary sinusitis in both samples, while half of the British females and males had associated dental changes. Within the pooled German samples, males had a higher prevalence rate than females; 71.43 percent of males and 59.46 percent of females had odontogenic maxillary sinusitis. However, testing for differences between the sexes within and across the two countries did not confirm a statistical significance (British females and males: χ^2=0.0000, p=1.000, d.f.=1; German females and males: χ^2=0.8309, p=0.3620, d.f.=1; British and German females: χ^2=0.4069, p=0.5236, d.f.=1; British and German males: χ^2=1.3588, p=0.2438, d.f.=1).

Age category	GB n/N (%)	D n/N (%)
<16	0/1 (0.0)	0/3 (0.0)
16-25	0/3 (0.0)	3/10 (30.0)
26-35	1/6 (16.67)	10/16 (62.5)
36-45	8/11 (72.73)	19/23 (82.61)
45+	4/5 (80.0)	4/7 (57.14)
Adult	0/1 (0.0)	7/8 (87.5)
Total	13/27 (48.15)	43/67 (64.18)

Table 5.6.16 Prevalence of odontogenic maxillary sinusitis expressed as a percentage of all maxillary sinus changes by age category and country – individual count (GB=pooled British samples, D=pooled German samples, n=number of individual affected, N=number of individuals observable).

Fig. 5.6.8 demonstrates the age-related rise in odontogenically induced maxillary sinusitis for all individuals who could be assigned to an age class. For the pooled British samples, a steady increase in prevalence can be found with increasing age starting in the young-middle adult category. The combined German samples demonstrated an earlier onset of odontogenic maxillary sinusitis beginning in the young adult age class, an increase until the middle age category and a slight drop in the oldest age band. Prevalence between younger (<16-35 years) and older (36-45+ years) was statistically significant in both combined samples (British samples: χ^2=17.0926, p=0.0000, d.f.=1; German samples: χ^2=6.2844, p=0.0122, d.f.=1).

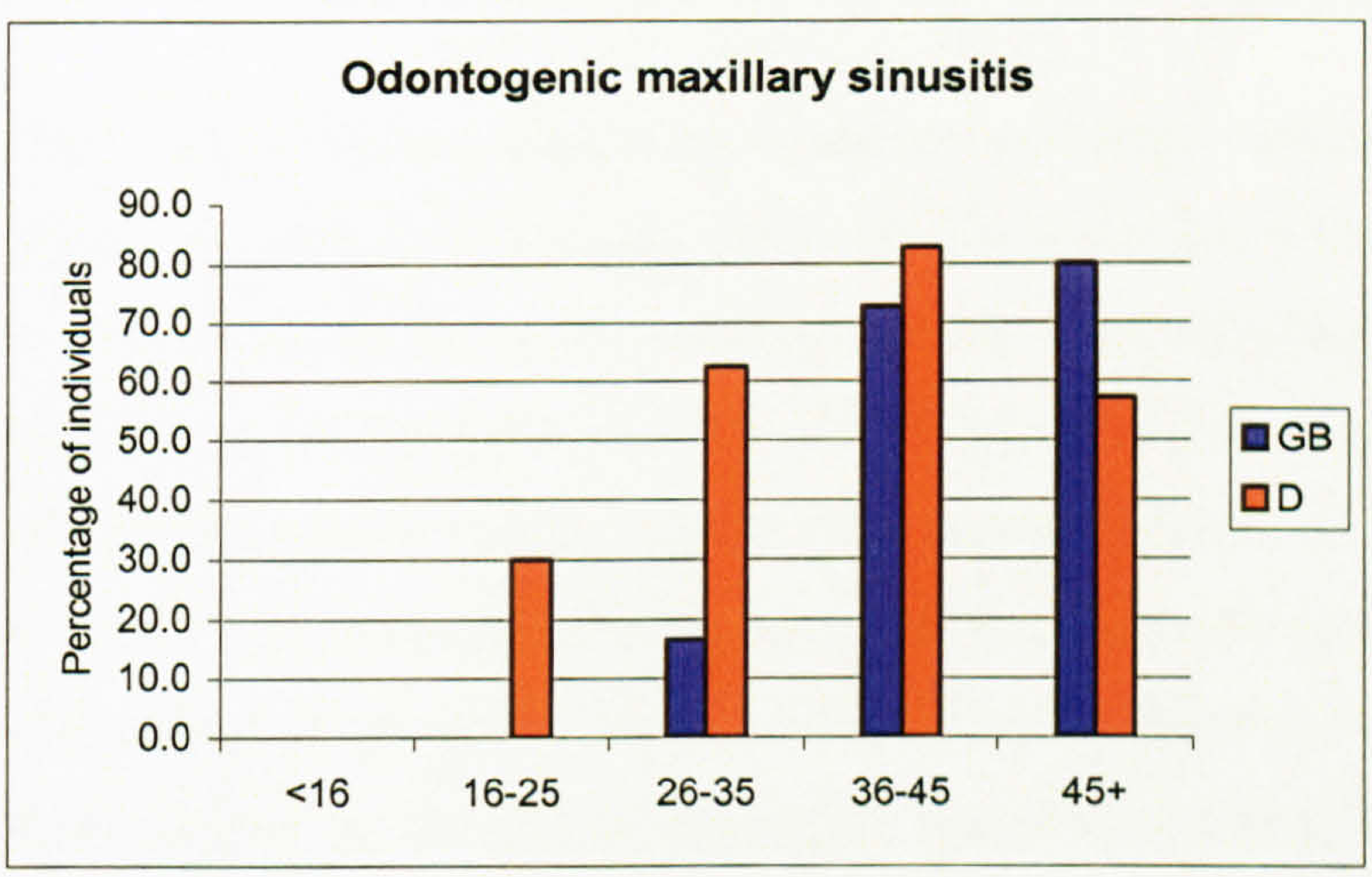


Fig 5.6.8 Prevalence of odontogenic maxillary sinusitis by age category (GB=pooled British samples, D=pooled German samples).

5.6.3 Rib periostitis

Periosteal new bone formation on visceral surfaces of ribs is presented by number of individuals affected in relation to the number of individuals observed, who had at least half of their 24 ribs preserved (Table 5.6.17 for the pooled British samples and Table 5.6.18 for pooled German samples).

Age category	Subadults	Females	Males	N/D	Total GB
Ribs	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)
<16	1/29 (3.45)	0/0 (0.0)	0/0 (0.0)	0/0 (0.0)	1/29 (3.45)
16-25	0/0 (0.0)	0/12 (0.0)	1/13 (0.0)	0/2 (0.0)	1/27 (3.7)
26-35	0/0 (0.0)	0/29 (0.0)	4/19 (0.0)	0/0 (0.0)	4/48 (8.33)
36-45	0/0 (0.0)	0/21 (0.0)	2/15 (0.0)	0/0 (0.0)	2/36 (10.0)
45+	0/0 (0.0)	0/9 (0.0)	0/9 (0.0)	0/0 (0.0)	0/18 (0.0)
Adult	0/0 (0.0)	0/1 (0.0)	0/0 (0.0)	0/0 (0.0)	0/1 (0.0)
Total GB	1/29 (3.45)	0/72 (0.0)	7/56 (12.5)	0/2 (0.0)	8/159 (5.03)

Table 5.6.17 Pooled British samples. Periosteal rib lesions by age category and sex – individual count (N/D=adult of undetermined sex, n=number of individuals affected, N=number of individuals with at least 12 ribs present, Total GB=overall prevalence for British samples).

Age category	Subadults	Females	Males	N/D	Total D
Ribs	n/N (%)	n/N (%)	n/N (%)	n/N (%)	n/N (%)
<16	0/11 (0.0)	0/0 (0.0)	0/0 (0.0)	0/0 (0.0)	0/11 (0.0)
16-25	0/0 (0.0)	0/7 (0.0)	0/1 (0.0)	0/0 (0.0)	0/8 (0.0)
26-35	0/0 (0.0)	1/28 (3.57)	1/12 (8.33)	0/0 (0.0)	2/40 (5.0)
36-45	0/0 (0.0)	1/13 (7.69)	1/17 (5.88)	0/0 (0.0)	2/30 (6.67
45+	0/0 (0.0)	1/5 (20.0)	0/5 (0.0)	0/0 (0.0)	1/10 (10.0)
Adult	0/0 (0.0)	0/0 (0.0)	0/0 (0.0)	0/1 (0.0)	0/1 (0.0)
Total D	0/11 (0.0)	3/53 (5.66)	2/35 (8.57)	0/1 (0.0)	5/100 (5.0)

Table 5.6.18 Pooled German samples. Periosteal rib lesions by age category and sex – individual count (N/D=adult of undetermined sex, n=number of individuals affected, N=number of individuals with at least 12 ribs present, Total D=overall prevalence for German samples).

Fig. 5.6.9 provides information on prevalence by age category for the pooled samples. As prevalence was generally low, results for individuals with periostitis of the ribs are detailed for the combined samples only. Individual skeletons with new bone formation on the visceral surface of ribs (rib periostitis) are listed in Appendix C6, Table 13. Prevalence varied considerably between different age categories but overall prevalence rates for affected individuals between the combined samples were very similar with 5.03 percent of individuals affected in Britain and 5.0 percent in Germany. This difference did not yield a statistically significant result (χ^2=0.0001, p=0.9910, d.f.=1).

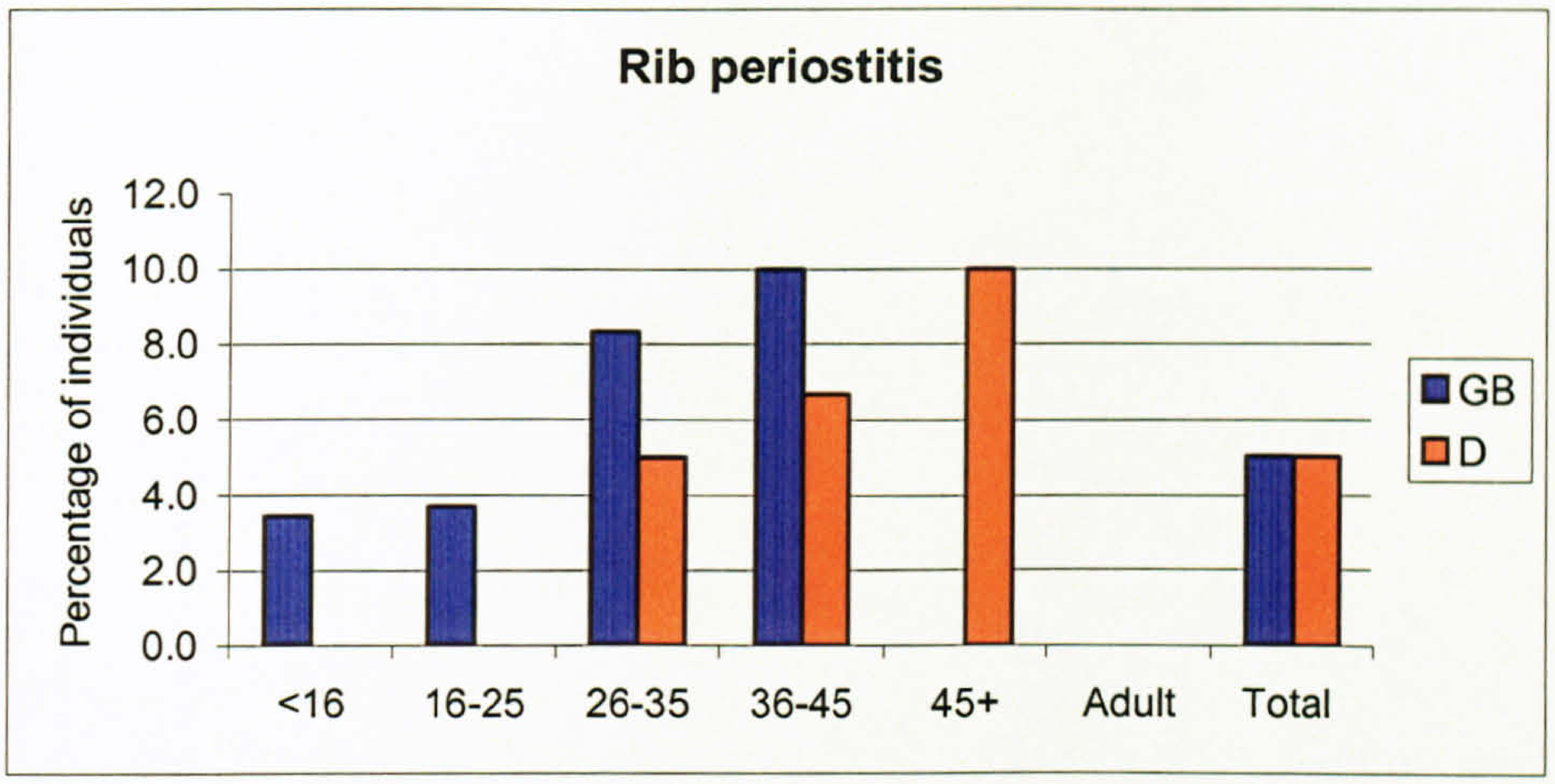


Fig.5.6.9 Prevalence of rib periostitis for pooled samples by age category – individual count (GB=pooled British samples, D=pooled German samples).

Despite having experienced very similar rates of rib periostitis, several differences between the two countries were noted. Periostitis on the visceral surface of ribs was present in all age categories in the British samples, with the exception of individuals estimated to be over 45 years old. Prevalence in the two youngest age bands was identical, but frequencies increased in the young-middle age category, and 10.0 percent of all skeletons in the middle-aged class showed signs of rib infection. In the combined German samples, periostitis of the ribs did not occur until young-middle age and prevalence increased until the old adult age category. Of the eight British skeletons, three (37.5 percent) had active new bone formation; among the five German individuals, two (40.0 percent) had lesions which were active at the time of their death.

Prevalence for periosteal new bone formation on the visceral aspect of ribs was also calculated by the number of affected ribs in relation to the number of ribs observable and results are presented in Table 5.6.19. Among the British samples, Castledyke South showed the highest values for rib periostitis with 3.2 percent of all ribs affected, followed by Apple Down with 3.08 percent. At Norton, there was no evidence of rib periostitis. Nusplingen had the highest prevalence among all samples; here 4.46 percent of all ribs displayed changes on their visceral surfaces. At Neresheim, 1.28 percent of ribs were affected and at Pleidelsheim only very few cases (0.68 percent) were observed. Prevalence for the pooled samples was almost twice as high in Britain (2.62 percent) than it was in Germany (1.37 percent).

Site	n	N	%	Site	n	N	%
Apple Down	42	1363	3.08	Neresheim	13	1015	1.28
Castledyke South	36	1125	3.2	Nusplingen	10	224	4.46
Norton	0	495	0.0	Pleidelsheim	6	878	0.68
Total GB	78	2983	2.62	Total D	29	2117	1.37

Table 5.6.19 Prevalence of rib periostitis by bone count (n=number of ribs with periostitis, N=number of ribs observed, Total GB=total of pooled British sample, Total D=total of pooled German sample).

5.6.5 Endocranial lesions

A total of 17 skeletons showed evidence of endocranial lesions (Appendix C6, Table 14). Only three cases (17.65 percent) occurred in the British samples, and all were males from the site of Apple Down. The remaining 14 individuals were from Neresheim (11.77 percent), Pleidelsheim (23.53 percent) and Nusplingen (47.06 percent). Table 5.6.21 (frontal bone) and Table 5.6.22 (occipital bone) display the percentage of endocranial lesions by site and sex. Parietal bone lesions occurred only in conjunction with frontal bone changes and were therefore not considered separately. In one of the two individuals with lesions on the temporal bones, they did occur together with other endocranial changes. Additionally, Table 5.6.22 displays endocranial lesions for all individuals with complete skulls (frontal, parietal, temporal and occipital bones present). It became apparent that more ectocranial lesions were present in the German samples, and here Nusplingen had the highest frequencies of frontal and occipital bone changes. On an individual basis, considering all endocranial lesions, again, the German skeletal remains had higher frequencies, although they failed to reach a statistically significant difference (χ^2=2.3307, p=0.1269, d.f.=1). Females and males in the pooled German sample had similar rates of endocranial changes (5.51 percent of females and 5.56 percent of males). However, subadults were most often affected with 11.11 percent showing some form of bone reaction on the internal table of the cranium. Immature, woven new bone formation and remodelled new bone formation was only seen in four of the skulls, respectively (23.53 percent, or 4 of 17 of all lesions), vessel impressions with and without pitting were the most commonly observed type of endocranial change (64.71 percent, or 11 of 17 skulls). Lesions still active at the time of death were found in two subadults (66.67 percent, or 2 of 3 individuals) as well as in a young-middle aged female (16.67 percent, or 1 of 6 individuals) and in an old adult male (33.33 percent, or 1 of 3 individuals).

Frontal bone	Apple Down n/N (%)	Castledyke South n/N (%)	Norton n/N (%)	Total GB n/N (%)	Neresheim n/N (%)	Nusplingen n/N (%)	Pleidelsheim n/N (%)	Total D n/N (%)
Subadults	0/19 (0.0)	0/6 (0.0)	0/8 (0.0)	0/33 (0.0)	0/13 (0.0)	0/5 (0.0)	2/19 (10.53)	2/37 (5.41)
Females	0/36 (0.0)	0/23 (0.0)	0/23 (0.0)	0/82 (0.0)	1/46 (2.17)	3/39 (7.69)	1/34 (2.94)	5/119 (4.2)
Males	3/25 (12.9)	0/20 (0.0)	0/9 (0.0)	3/54 (5.56)	0/31 (0.0)	2/46 (4.35)	1/26 (3.85)	3/103 (2.91)
N/D	0/1 (0.0)	0/0 (0.0)	0/2 (0.0)	0/3 (0.0)	0/1 (0.0)	0/2 (0.0)	0/2 (0.0)	0/5 (0.0)
Total	3/81 (3.7)	0/49 (0.0)	0/42 (0.0)	3/172 (1.74)	1/91 (1.1)	5/92 (5.43)	4/81 (4.94)	10/264 (3.79)

Table 5.6.20 Endocranial lesions on the frontal bone (n=number of frontal bones displaying lesions, N=number of frontal bones observed, N/D=adults of undetermined sex).

Occipital bone	Apple Down n/N (%)	Castledyke South n/N (%)	Norton n/N (%)	Total GB n/N (%)	Neresheim n/N (%)	Nusplingen n/N (%)	Pleidelsheim n/N (%)	Total D n/N (%)
Subadults	0/20 (0.0)	0/6 (0.0)	0/5 (0.0)	0/31 (0.0)	0/8 (0.0)	1/4 (25.0)	0/16 (0.0)	1/28 (3.57)
Females	0/37 (0.0)	0/15 (0.0)	0/19 (0.0)	0/71 (0.0)	0/21 (0.0)	1/29 (3.45)	0/31 (0.0)	1/81 (1.24)
Males	0/25 (0.0)	0/17 (0.0)	0/6 (0.0)	0/48 (0.0)	0/16 (0.0)	2/43 (4.65)	0/26 (0.0)	2/85 (2.35)
N/D	0/1 (0.0)	0/0 (0.0)	0/1 (0.0)	0/2 (0.0)	0/0 (0.0)	0/2 (0.0)	0/0 (0.0)	0/2 (0.0)
Total	0/83 (0.0)	0/38 (0.0)	0/31 (0.0)	0/152 (0.0)	0/45 (0.0)	4/78 (5.13)	0/73 (0.0)	4/196 (2.04)

Table 5.6.21. Endocranial lesions on the occipital bone (n=number of occipital bones displaying lesions, N=number of occipital bones observed, N/D=adults of undetermined sex).

Complete skull	Apple Down n/N (%)	Castledyke South n/N (%)	Norton n/N (%)	Total GB n/N (%)	Neresheim n/N (%)	Nusplingen n/N (%)	Pleidelsheim n/N (%)	Total D n/N (%)
Subadults	0/20 (0.0)	0/2 (0.0)	0/1 (0.0)	0/23 (0.0)	0/8 (0.0)	1/3 (0.0)	2/16 (12.5)	3/27 (11.11)
Females	0/36 (0.0)	0/7 (0.0)	0/11 (0.0)	0/54 (0.0)	1/29 (3.45)	4/44 (9.09)	1/36 (2.78)	6/109 (5.51)
Males	3/25 (0.0)	0/13 (0.0)	0/4 (0.0)	3/42 (7.14)	1/18 (5.56)	3/43 (4.35)	1/29 (3.45)	5/90 (5.56)
N/D	0/1 (0.0)	0/0 (0.0)	0/2 (0.0)	0/3 (0.0)	0/0 (0.0)	0/2 (0.0)	0/0 (0.0)	0/2 (0.0)
Total	3/82 (3.66)	0/22 (0.0)	0/18 (0.0)	3/122 (2.46)	2/55 (3.64)	8/92 (5.43)	4/81 (4.94)	14/228 (6.14)

Table 5.6.22 All endocranial lesions on individuals with complete skulls (n=number of individuals displaying lesions, N=number of individuals with skulls present, N/D=adults of undetermined sex).

5.7 CONGENITAL AND DEVELOPMENTAL ANOMALIES

5.7.1 Congenital anomalies of the spine (other than spina bifida occulta)

Appendix C7, Table 1 provides a list of all individuals with spinal anomalies other than spina bifida occulta. At Apple Down, twelve adult individuals had evidence of transitional vertebrae; seven were female and five male (Table 5.7.1). One middle-aged female had rib facets on her seventh cervical vertebra. Lumbarisation occurred in three females and males, and sacralisation in two males only. Two females had thirteen thoracic vertebrae where the first lumbar vertebra had taken on the characteristics of a thoracic vertebra, including ribs facets on the vertebral body. Since 30 females had L1 preserved, the prevalence for thoraco-lumbar transitional vertebrae and lumbar ribs was 6.67 percent for females and 3.51 percent for the adult Apple Down sample. The prevalence for lumbarisation was 8.82 percent for females, 11.54 percent for males and 9.84 percent for the total sample. Sacralisation prevalence was much lower, with 8.33 percent for males and 3.45 percent for the entire adult sample. One Apple Down female (AP162) had no costal facets on the bodies of her ninth, tenth and twelfth thoracic vertebrae, indicating cranial shifting. Cranial shifting had also occurred in the female with cervical ribs (3.23 percent of females). Of the twelve Apple Down individuals, eight (66.67 percent) had experienced caudal and four (33.33 percent) cranial shifts

Apple Down	Females (%)	Males (%)	N/D (%)	Total (%)
Cervical ribs	1/31 (3.23)	0/27 (0.0)	0/1 (0.0)	1/58 (1.72)
Lumbar ribs	2/30 (6.67)	0/26 (0.0)	0/1 (0.0)	2/57 (3.51)
Lumbarisation	3/34 (8.82)	3/26 (11.54)	0/1 (0.0)	6/61 (9.84)
Sacralisation	0/33 (0.0)	2/24 (8.33)	0/1 (0.0)	2/58 (3.45)

Table 5.7.1 Apple Down prevalence for congenital conditions of the axial skeleton (other than spina bifida occulta) (N/D=adults of undetermined sex).

Congenital disease of the vertebral column at Castledyke South affected six females and seven males. Table 5.7.2 lists details about individual congenital anomalies by sex. Lumbar ribs were found in one male (5.26 percent). Lumbarisation occurred in three adult females (7.89 percent) and two males (9.52 percent). Sacralisation was present in three females (7.5 percent) and four males (19.05 percent), but none of the unsexed adults. A total of thirteen individuals was affected at Castledyke South; six (46.15 percent) had evidence of caudal shifting, while slightly more (53.85 percent) showed cranial shifts.

Castledyke South	Females (%)	Males (%)	N/D (%)	Total (%)
Cervical ribs	0/14 (0.0)	0/19 (0.0)	0/1 (0.0)	0/33 (0.0)
Lumbar ribs	0/31 (0.0)	1/19 (5.26)	0/1 (0.0)	1/51 (1.96)
Lumbarisation	3/38 (7.89)	2/21 (9.52)	0/0 (0.0)	5/59 (8.48)
Sacralisation	3/40 (7.5)	4/21 (19.05)	0/0 (0.0)	7/61 (11.48)

Table 5.7.2 Castledyke South prevalence for congenital conditions of the axial skeleton (other than spina bifida occulta) (N/D=adults of undetermined sex).

At Norton, spinal congenital disease was found in two females and one male (Table 5.7.3). Lumbar ribs were not observed, while lumbarisation affected one female (10.0 percent) and sacralisation was present in one female and one male (7.69 percent and 14.29 percent). Of the three individuals with transitional vertebrae at Norton, one (33.33 percent) had caudal shifts and two (66.67 percent) showed cranial shifting.

Norton	Females (%)	Males (%)	N/D (%)	Total (%)
Cervical ribs	0/9 (0.0)	0/5 (0.0)	0/1 (0.0)	0/15 (0.0)
Lumbar ribs	0/7 (0.0)	0/5 (0.0)	0/0 (0.0)	0/12 (0.0)
Lumbarisation	1/10 (10.0)	0/7 (0.0)	0/2 (0.0)	1/19 (5.26)
Sacralisation	1/13 (7.69)	1/7 (14.29)	0/1 (0.0)	2/21 (9.52)

Table 5.7.3 Norton prevalence for congenital conditions of the axial skeleton (other than spina bifida occulta) (N/D=adults of undetermined sex).

Neresheim yielded only four individuals with some form of congenital anomaly of the spine and the results are listed in Table 5.7.4. One female had a lumbar rib (5.88 percent), one other female showed sacralisation of L5 (4.0 percent) and one male lumbarisation of S1 (4.55 percent). One female had evidence of a 'butterfly' vertebra where the body of the fifth lumbar vertebra consisted of two separate parts (4.76 percent of all female L5s, or 2.27 percent of all fifth lumbar vertebrae in the Neresheim adult sample). Altogether, two individuals had experienced caudal shifting (66.67 percent) and one a cranial shift (33.33 percent).

Neresheim	Females (%)	Males (%)	N/D (%)	Total (%)
Cervical ribs	0/23 (0.0)	0/17 (0.0)	0/0 (0.0)	0/4 (0.0)
Lumbar ribs	1/17 (5.88)	0/19 (0.0)	0/1 (0.0)	1/37 (2.7)
Lumbarisation	0/21 (0.0)	1/22 (4.55)	0/1 (0.0)	1/44 (2.27)
Sacralisation	1/25 (4.0)	0/15 (0.0)	0/1 (0.0)	1/41 (2.44)

Table 5.7.4 Neresheim prevalence for congenital conditions of the axial skeleton (other than spina bifida occulta) (N/D=adults of undetermined sex).

Results for Nusplingen are tabulated in Table 5.7.5. Here, one male (8.33 percent) had lumbarisation, while one female (6.67 percent) and one male (9.09 percent) had their final lumbar vertebra fused to the sacrum. One adult male (NU41) displayed incomplete fusion of the first and second sacral element where a small oval gag remained visible on the left posterior aspect of this bone. This finding could not be related to any form of transitional vertebrae and was probably cause by some developmental malfusion of the two sacral segments. One caudal (33.33 percent) and two (66.67 percent) cranial shifts had occurred in the Nusplingen sample.

Nusplingen	Females (%)	Males (%)	N/D (%)	Total (%)
Cervical ribs	0/6 (0.0)	0/5 (0.0)	0/0 (0.0)	0/11 (0.0)
Lumbar ribs	0/9 (0.0)	0/5 (0.0)	0/0 (0.0)	0/14 (0.0)
Lumbarisation	0/12 (0.0)	1/12 (8.33)	0/0 (0.0)	1/24 (4.17)
Sacralisation	1/15 (6.67)	1/11 (9.09)	0/0 (0.0)	2/26 (7.69)

Table 5.7.5 Nusplingen prevalence for congenital conditions of the axial skeleton (other than spina bifida occulta) (N/D=adults of undetermined sex).

At Pleidelsheim, one male showed evidence for occipitalisation of the first cervical vertebra (3.13 percent) and two males (2.09 percent) had experienced sacralisation (Table 5.7.6). One male (PL40) showed changes of his second and third right ribs. The second rib displayed a broadened body and the third took on the morphological features of the second rib, indicating a cranial border shift. Altogether, cranial border shifting had occurred in three (75.0 percent) of all affected individuals and a caudal shift was observed in one individual (25.0 percent).

Pleidelsheim	Females (%)	Males (%)	N/D (%)	Total (%)
Occipitalisation	0/29 (0.0)	1/32 (3.13)	0/0 (0.0)	1/61 (1.64)
Cervical ribs	0/23 (0.0)	0/30 (0.0)	0/0 (0.0)	0/53 (0.0)
Lumbar ribs	0/24 (0.0)	0/16 (0.0)	0/0 (0.0)	0/40 (0.0)
Lumbarisation	0/25 (0.0)	0/18 (0.0)	0/0 (0.0)	0/43 (0.0)
Sacralisation	0/26 (0.0)	2/22 (9.09)	0/0 (0.0)	2/48 (4.17)

Table 5.7.6 Pleidelsheim prevalence for congenital conditions of the axial skeleton (other than spina bifida occulta) (N/D=adults of undetermined sex).

Results for pooled samples by country and sex are presented in Table 5.7.7. The number of individuals with cervical and lumbar ribs was too low to be tested for a statistically significant difference and atlas occipitalisation only occurred once. When comparing prevalence for lumbarisation between the countries, British individuals had significantly higher rates (χ^2=5.5604, p=0.0183, d.f.=1), while frequencies for sacralisation were not significantly different (χ^2=1.349, p=0.2453, d.f.=1). British males displayed high rates of sacralisation, compared to other sub-samples. For lumbarisation, frequencies between the sexes in the British samples were more uniform. Again, for the German sites the number of individuals with the condition were too low to allow for statistical testing.

	Lumbar ribs	Lumbarisation	Sacralisation
GB Females (%)	2/68 (2.94)	7/82 (8.54)	4/86 (4.65)
GB Males (%)	1/50 (2.0)	5/54 (9.26)	7/52 (13.46)
Total GB (%)	3/118 (2.54)	12/136 (8.82)	11/138 (7.97)
D Females (%)	1/50 (2.0)	0/58 (0.0)	2/66 (3.03)
D Males (%)	0/40 (0.0)	2/52 (3.85)	3/48 (6.25)
Total D (%)	1/90 (1.11)	2/110 (1.81)	5/114 (4.39)

Table 5.7.7 Prevalence for congenital conditions of the axial skeleton (other than spina bifida occulta) for pooled British and German samples of known sex (Total GB=pooled British samples, Total D=pooled German samples).

A caudal direction of border shifting was slightly more common in the British samples (53.57 percent of 28 individuals) than a cranial shift (46.43 percent, or 13 of 28 individuals). British females had more caudal (60.0 percent, or 9 of 15 individuals) than cranial shifts (40.0 percent, or 6 of 15 individuals), while British males had slightly more cranial border shifting (53.85 percent, 7 of 13 individuals) than caudal shifts (46.15 percent, or 6 of 13 individuals). In contrast, cranial shifts occurred more often in the German samples (60.0 percent, or 6 of 10 individuals) than caudal shifting (40.0 percent, or 4 of 10 individuals). Females had twice as many cranial shifts (66.67 percent, or 2 of 3 individuals) than caudal one (33.33 percent, or 1 of 3 individuals). Equally, males showed more cranial border shifting (71.43 percent, or 5 of 7 individuals) than caudal shifts (28.57 percent, or 2 of 7 individuals).

5.9.2 Spina bifida occulta (SBO)

Frequencies for sacral spina bifida occulta (SBO) can be found in Tables 5.7.8 (for individual sites), 5.7.9 and Fig. 5.7.1 (for pooled samples). In addition, Appendix C9, Table 2 provides a list of affected individuals. All cases of spina bifida occulta (sacral and non-sacral) were identified as anomalies which did not involve any neural tube defects, e.g., the margins of the open neural arches were not bowed in an outward direction, which would indicate protrusion of the neural chord. A total of nineteen individuals were found to have SBO occurring on the sacrum.

	Apple Down				Castledyke South				Norton		
	n	N	%		n	N	%		n	N	%
F	1	33	3.03	F	3	40	7.5	F	1	13	7.69
M	0	24	0	M	5	21	23.81	M	1	7	14.29
N/D	0	1	0	N/D	0	0	0	N/D	0	1	0
Total	1	58	1.72	Total	8	61	13.11	Total	2	21	9.52
	Neresheim				Nusplingen				Pleidelsheim		
	n	N	%		n	N	%		n	N	%
F	2	25	8.0	F	2	15	13.33	F	0	26	0
M	1	15	6.67	M	0	11	0	M	3	22	13.64
N/D	0	1	0	N/D	0	0	0	N/D	0	0	0
Total	3	41	7.32	Total	2	26	7.69	Total	3	48	6.25

Table 5.7.8 Prevalence of spina bifida occulta by individuals affected in relation to individuals with sacra present (n=number of individuals affected, N=number of individuals observable, F=females, M=males, N/D=adults of undetermined sex).

British frequencies for sacral SBO ranged from as low as 1.72 percent for Apple Down to as high as 13.11 percent for Castledyke South, and Norton was situated between these two extremes with 9.52 percent. With the exception of Apple Down, where no male individuals were affected, males at the other two British sites had a higher prevalence than females. The three German sites showed more evenly distributed frequencies ranging between 6.25 percent and 7.69 percent. Females and males at Neresheim had similar rates, at Nusplingen only females had SBO and at Pleidelsheim only males were affected.

There was no statistical significant difference between individuals from the English and German samples of having spina bifida occulta at the sacral level (χ^2=0.0743, p=0.7852, d.f.=1). Despite the higher prevalence of SBO for British males, again, no statistically significant difference was found within British males and females (χ^2=1.4476, p=0.2289, d.f.=1). The number of affected individuals from German samples was too small for chi-squared testing.

	British samples				German samples		
	n	N	%		n	N	%
Females	5	86	5.81	Females	4	66	6.06
Males	6	52	11.54	Males	4	48	8.33
N/D	0	2	0.0	N/D	0	1	0.0
Total	11	140	7.86	Total	8	115	6.96

Table 5.7.9 Prevalence of individuals with spina bifida occulta for pooled samples (n=number of individuals affected, N=number of individuals observed, N/D=adults of undetermined sex).

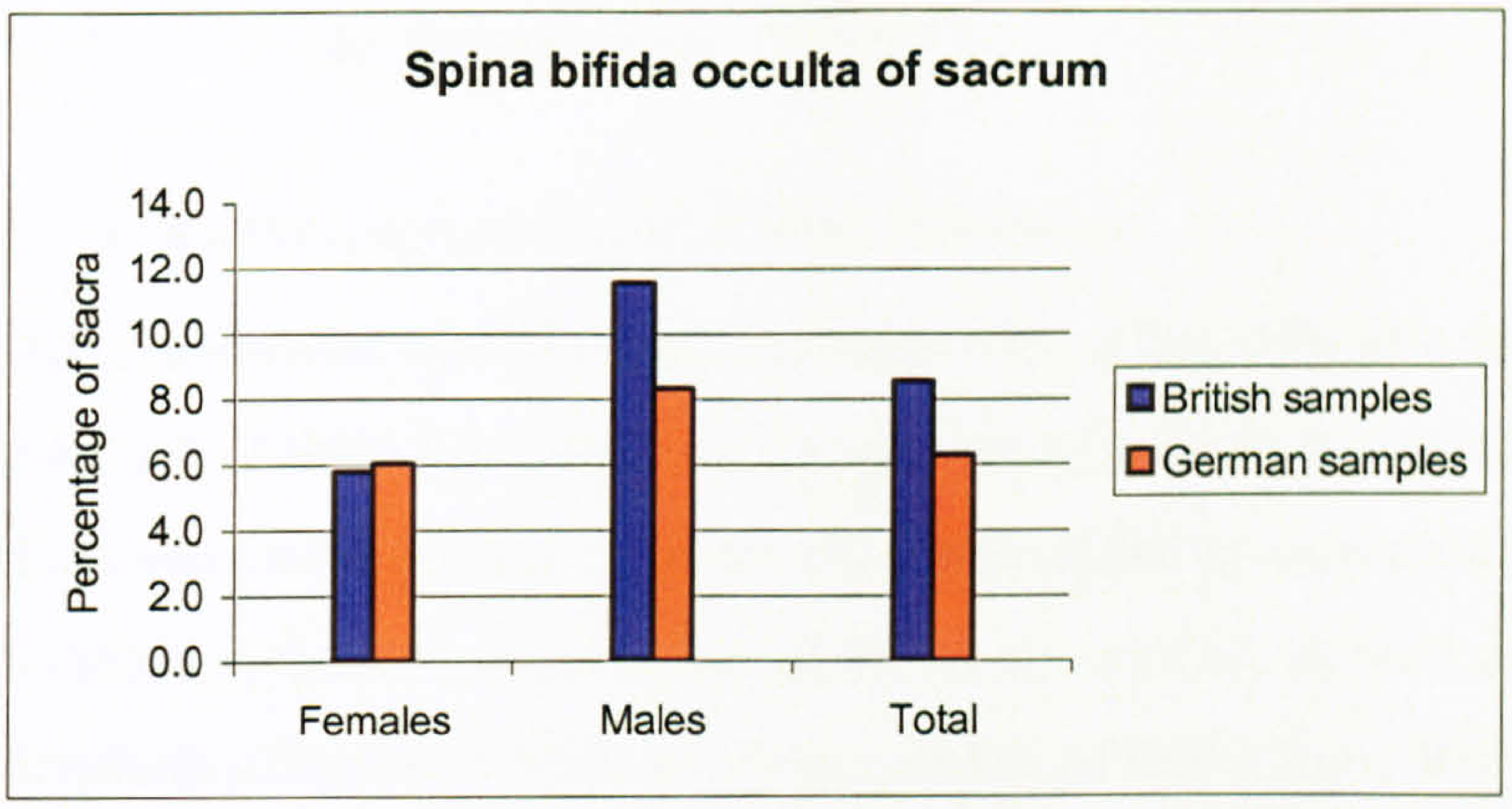


Fig. 5.7.1 Spina bifida occulta of the sacrum in pooled British and German samples by number of sacra affected.

Results for SBO occurring at vertebral elements other than the sacrum are displayed in Table 5.7.10. Five individuals, one from Apple Down, and two from Castledyke South, as well as two from the German site of Nusplingen, had SBO of a non-sacral vertebral element. Three adult individuals were female and two were male. One adult female from Apple Down (AP55) showed non-union of the posterior arch of the atlas (1.06 percent), while one male from Castledyke South (CS90) showed non-fusion at the posterior midline of C1 (1.79 percent). In a young adult female from the same site (CS134), the posterior aspect of the first segment of the coccyx was not fused (9.09 percent). The first cervical vertebra of NU137, a female, had a cleft on the posterior atlas (2.63 percent). One Nusplingen male (NU82) displayed non-union of the spinous process of the eleventh lumbar vertebra (6.67 percent). As the number of affected individuals in both countries was low, no statistical tests were applied.

Site	C1	%	T11	%	Coccyx	%
Apple Down	1/94	1.06	0/83	0.0	0/19	0.0
Castledyke South	1/56	1.79	0/59	0.0	1/11	9.09
Norton	0/35	0.0	0/17	0.0	0/3	0.0
Total GB	2/185	1.08	0/159	0.0	1/33	3.03
Neresheim	0/83	0.0	0/28	0.0	0/4	0.0
Nusplingen	1/38	2.63	1/15	6.67	0/0	0.0
Pleidelsheim	0/74	0.0	0/47	0.0	0/4	0.0
Total D	1/195	0.51	1/90	1.11	0/8	0.0

Table 5.7.10. Prevalence of non-sacral spina bifida occulta by site (C1=1st cervical vertebra (atlas), T11=11th thoracic vertebra, Total GB=pooled British samples, Total D=pooled German samples).

5.8 METABOLIC DISORDERS

5.8.1 Iron deficiency anaemia (Cribra orbitalia)

All individuals with lesions consistent with cribra orbitalia are listed in Appendix C8, Tables 1-6. Tables 5.8.1 and 5.8.2 present results for cribra orbitalia prevalence for the British and German sites, respectively. Both tables contain data by number of orbits affected in relation to the number of orbits observable, as well as by number of individuals affected in relation to the number of individuals with both their orbits present. As the number of orbits with cribra orbitalia from the left and right side was not statistically different, prevalence for both sides was combined (British samples: χ^2=0.1172, p=0.7321, d.f.=1; German samples: χ^2=0.1346, p=0.7137, d.f.=1

Cribra orbitalia	Apple Down		Castledyke South		Norton	
·	Orbits n/N (%)	Individuals n*/N* (%)	Orbits n/N (%)	Individuals n*/N* (%)	Orbits n/N (%)	Individuals n*/N* (%)
<16	5/36 (13.89)	3/16 (18.75)	12/24 (50.0)	6/9 (66.67)	2/14 (14.29)	1/6 (16.67)
Females	2/63 (3.18)	1/25 (4.0)	1/38 (2.63)	1/12 (8.33)	0/40 (0.0)	0/14 (0.0)
Males	2/40 (5.0)	1/16 (6.25)	2/42 (4.76)	2/19 (10.53)	0/21 (0.0)	0/9 (0.0)
N/D	0/2 (0.0)	0/1 (0.0)	0/0 (0.0)	0/0 (0.0)	0/4 (0.0)	0/2 (0.0)
Total GB	9/141 (6.38)	5/58 (8.62)	15/104 (14.42)	9/40 (22.5)	2/79 (2.53)	1/31 (3.23)

Table 5.8.1 Prevalence of cribra orbitalia for British sites (n=number of orbits affected, N=number of orbits preserved, n*=number of individuals affected, N*=number of individuals with both orbits preserved, <16=subadults below the age of 16 years, N/D=adults of undetermined sex).

Prevalence of cribra orbitalia within the British sites varied considerably. At Norton, only one individual (3.23 percent) had both orbits affected (2.53 percent). Frequencies at Apple Down were higher, with five individuals (8.62 percent) having nine orbits with porotic changes (6.38 percent). The highest prevalence was found at Castledyke South; here, nine individuals (22.5 percent) had 15 orbits involved (14.42 percent). Differences between the three samples proved to be statistically significant with Castledyke South having significantly higher rates (χ^2=6.7321, p=0.0345, d.f.=2). The subgroup consistently showing the highest prevalence rates were individuals under the age of 16 years and among adults, males from the sites of Apple Down and Castledyke South were more often affected than females. This difference between non-adults and adults for the pooled British samples was statistically significant (χ^2=16.2325, p=0.0000, d.f.=1). However, differences between British females and males could not be tested because too few individuals were affected to provide a statistically sound basis.

Cribra orbitalia	Neresheim		Nusplingen		Pleidelsheim	
	Orbits n/N (%)	Individuals n*/N* (%)	Orbits n/N (%)	Individuals n*/N* (%)	Orbits n/N (%)	Individuals n*/N* (%)
<16	24/36 (66.67)	15/21 (71.43)	9/13 (69.23)	5/7 (71.43)	20/38 (52.63)	11/17 (64.71)
Females	18/79 (22.78)	12/34 (35.29)	26/81 (32.1)	14/36 (38.89)	6/75 (8.0)	4/34 (11.77)
Males	28/58 (48.28)	16/27 (59.26)	26/98 (26.53)	13/44 (29.5)	8/65 (12.31)	4/27 (14.82)
N/D	0/1 (0.0)	0/0 (0.0)	2/4 (50.0)	1/2 (50.0)	0/4 (0.0)	0/1 (0.0)
Total D	71/173 (41.04)	43/82 (52.44)	63/196 (32.14)	33/89 (37.08)	34/182 (18.68)	19/79 (25.64)

Table 5.8.2 Prevalence of cribra orbitalia for German sites (n=number of orbits affected, N=number of orbits preserved, n*=number of individuals affected, N*=number of individuals with both orbits preserved, <16=subadults below the age of 16 years, N/D=adults of undetermined sex).

Among the German sites (Table 5.8.2), Pleidelsheim had the lowest prevalence of cribra orbitalia – approximately one-quarter of all individuals (25.64 percent) had 34 orbits affected (18.68 percent). At Nusplingen, more than one-third of all skeletons (37.08 percent) had 63 orbits with cribra orbitalia (32.14 percent). The site of Neresheim yielded the highest frequencies. Here more than half of all individuals (52.44 percent) had 71 orbits with cribra orbitalia (41.04 percent). Again, differences in prevalence between the three sites proved to be statistically significant (χ^2=13.8135, p=0.0010, d.f.=2). Within the German sites, non-adults were the subgroup displaying the highest frequencies, and the difference between non-adult and sexed adult frequencies was highly significant (χ^2=22.1133, p=0.0000, d.f.=1). Among the adults, males from Neresheim and Pleidelsheim had more cribra orbitalia than females, while at Nusplingen more females had changes on their orbits. However, in the pooled German samples the difference between female and male cribra orbitalia did not prove to be statistically significant (χ^2=0.4579, p=0.4592, d.f.=1).

Table 5.8.3 and Fig. 5.8.1 display cribra orbitalia prevalence for the combined samples by individuals affected. Comparing overall frequencies between the pooled samples proved to be statistically significant, with German individuals displaying more orbital changes (χ^2=28.2422, p=0.0000, d.f.=1). Although in both countries non-adults had the most lesions, non-adults from the combined German samples had significantly more cribra orbitalia compared to their British counterparts (χ^2=11.2479, p=0.0008, d.f.=1).

Cribra orbitalia	Pooled British samples		Pooled German samples	
	Orbits n/N (%)	Individuals n*/N* (%)	Orbits n/N (%)	Individuals n*/N* (%)
Non-adults	19/74 (25.68)	10/31 (32.26)	53/87 (60.92)	31/45 (68.89)
Females	3/141 (2.13)	2/51 (3.92)	50/235 (21.28)	30/104 (28.85)
Males	6/103 (5.83)	3/44 (6.82)	62/221 (28.05)	33/99 (33.33)
N/D	0/6 (0.0)	0/3 (0.0)	3/8 (37.5)	1/2 (50.0)
Total	28/324 (8.64)	15/129 (11.63)	268/551 (30.49)	95/250 (38.55)

Table 5.8.3 Prevalence of cribra orbitalia of combined British and German samples. (n=number of orbits affected, N=number of orbits preserved, n*=number of individuals affected, N*=number of individuals with both orbits preserved, N/D=adults of undetermined sex).

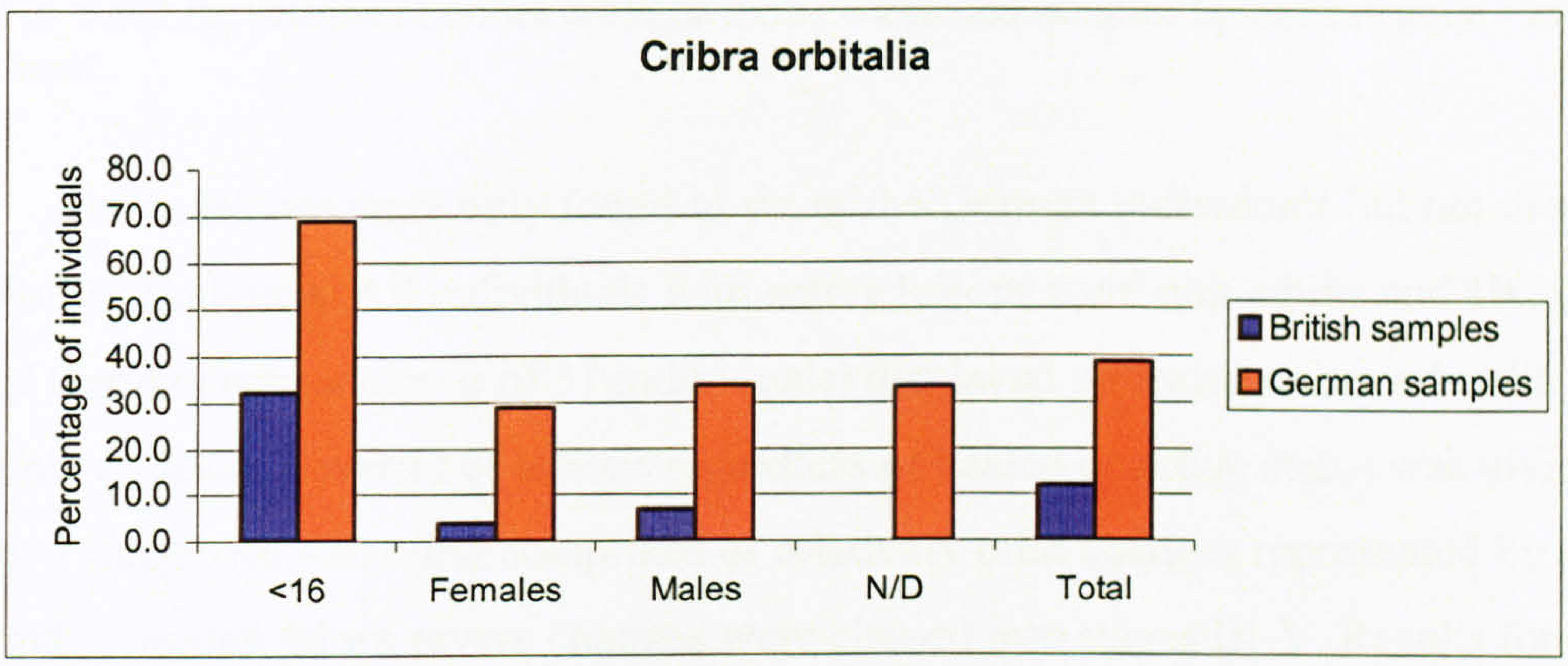


Fig. 5.8.1 Prevalence of cribra orbitalia in the combined samples – individual count (<16=subadults below the age of 16 years, N/D=adults of undetermined sex).

Table 5.8.4 and Fig. 5.8.2 investigate the distribution of cribra orbitalia prevalence by age category. As already demonstrated, non-adults from both countries were at a higher risk of displaying lesions. For the pooled British samples, young-middle aged adults had the lowest frequencies among all adult age categories. However, the number of affected individuals was low. Within the German adult age categories a constant decrease in cribra orbitalia prevalence was evident. However, rates rose again in the old adult age category.

Age category	GB n/N (%)	D n/N (%)
<16	10/31 (32.26)	31/45 (68.89)
16-25	1/20 (5.0)	10/23 (43.48)
26-35	1/35 (2.86)	23/87 (26.44)
36-45	2/30 (6.67)	16/61 (26.23)
45+	1/12 (8.33)	14/29 (48.28)
Adult	0/1 (0.0)	1/5 (20.0)
Total	15/129 (11.63)	95/250 (38.37)

Table 5.8.4 Prevalence of cribra orbitalia by age category and country– individual count (GB=pooled British samples, D=pooled German samples, n=number of individuals affected, N=number of individuals observable).

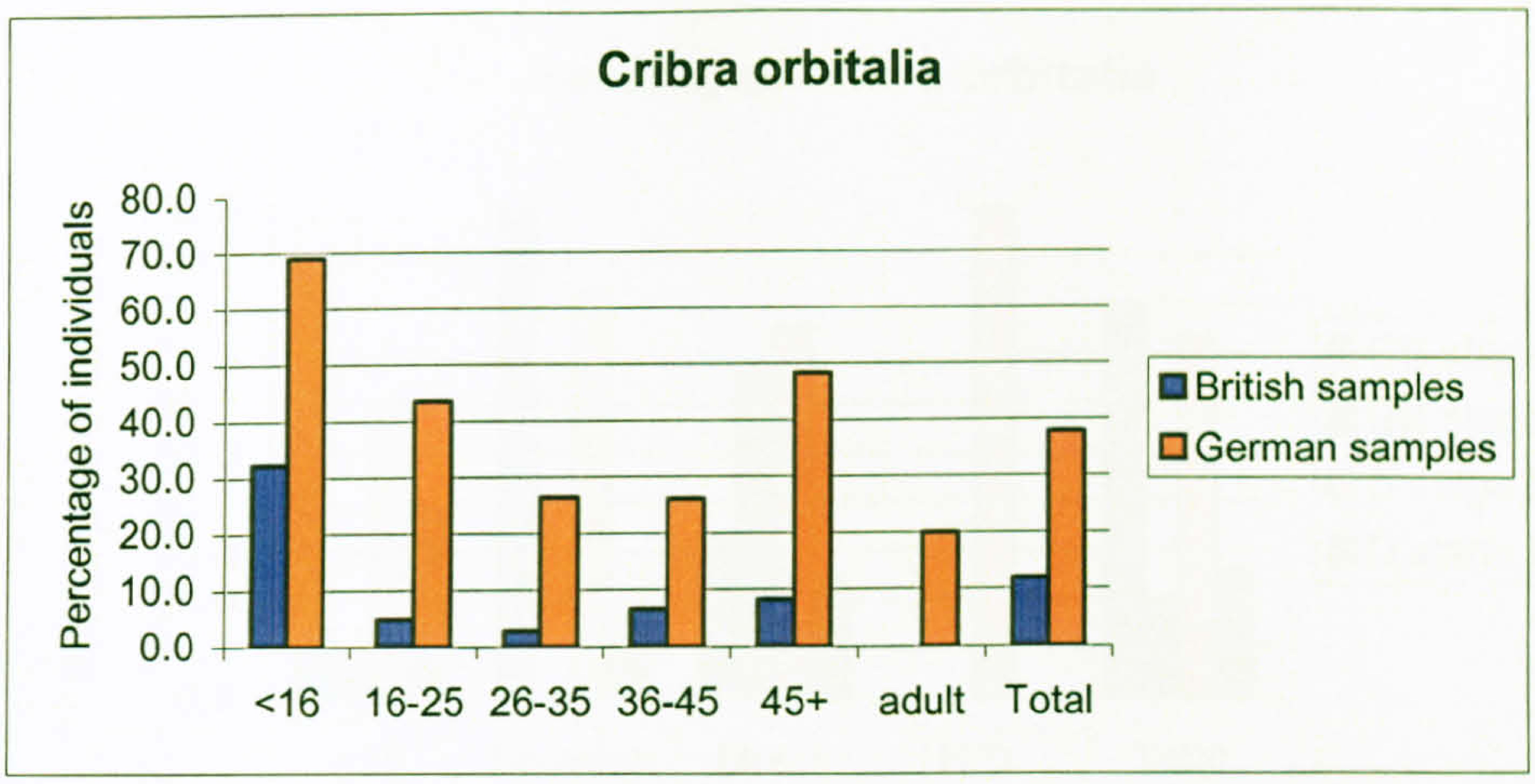


Fig. 5.8.2 Prevalence of cribra orbitalia in the combined samples by age category – individual count.

Active lesions were only found in six of the German individuals but not in any of the British skeletons. All individuals with active lesions were non-adults and 19.36 percent of German non-adults (6 of 31 individuals) displayed unhealed cribra orbitalia at their time of death. Severity of lesions regardless of healed or active status was divided into two categories – the first comprised of relatively mild changes represented by stage I and II lesions. More severe changes were classed into stages III-V. Results for severity of cribra orbitalia are tabulated in Table 5.8.5 and Fig. 5.8.3. In both countries slight expressions of cribra orbitalia prevailed (stage I and II). However, British males had more severe changes (stage III-V) than any other subgroup but, again, the number of affected male individuals was very low. Among non-adults from the pooled British samples, only 10.0 percent exhibited more severe expressions of cribra orbitalia. Subadults from the German samples had a higher prevalence of grade III-V changes with almost 40.0 percent of this subgroup displaying severe expressions of cribra orbitalia.

	British samples		German samples	
Stage	I+II	III-V	I+II	III-V
<16	9/10 (90.0)	1/10 (10.0)	19/31 (61.23)	12/31 (38.71)
Females	2/2 (100.0)	0/0 (0.0)	25/30 (83.33)	5/30 (16.67)
Males	1/3 (33.33)	2/3 (66.67)	25/33 (75.76)	8/33 (24.24)
N/D	0/0 (0.0)	0/0 (0.0)	1/1 (100.0)	0/1 (0.0)
Total	12/15 (80.0)	3/15 (20.0)	70/95 (75.76)	25/95 (24.24)

Table 5.8.5 Prevalence of cribra orbitalia by severity – individual count (<16=subadults below the age of 16 years, N/D=adults of undetermined sex).

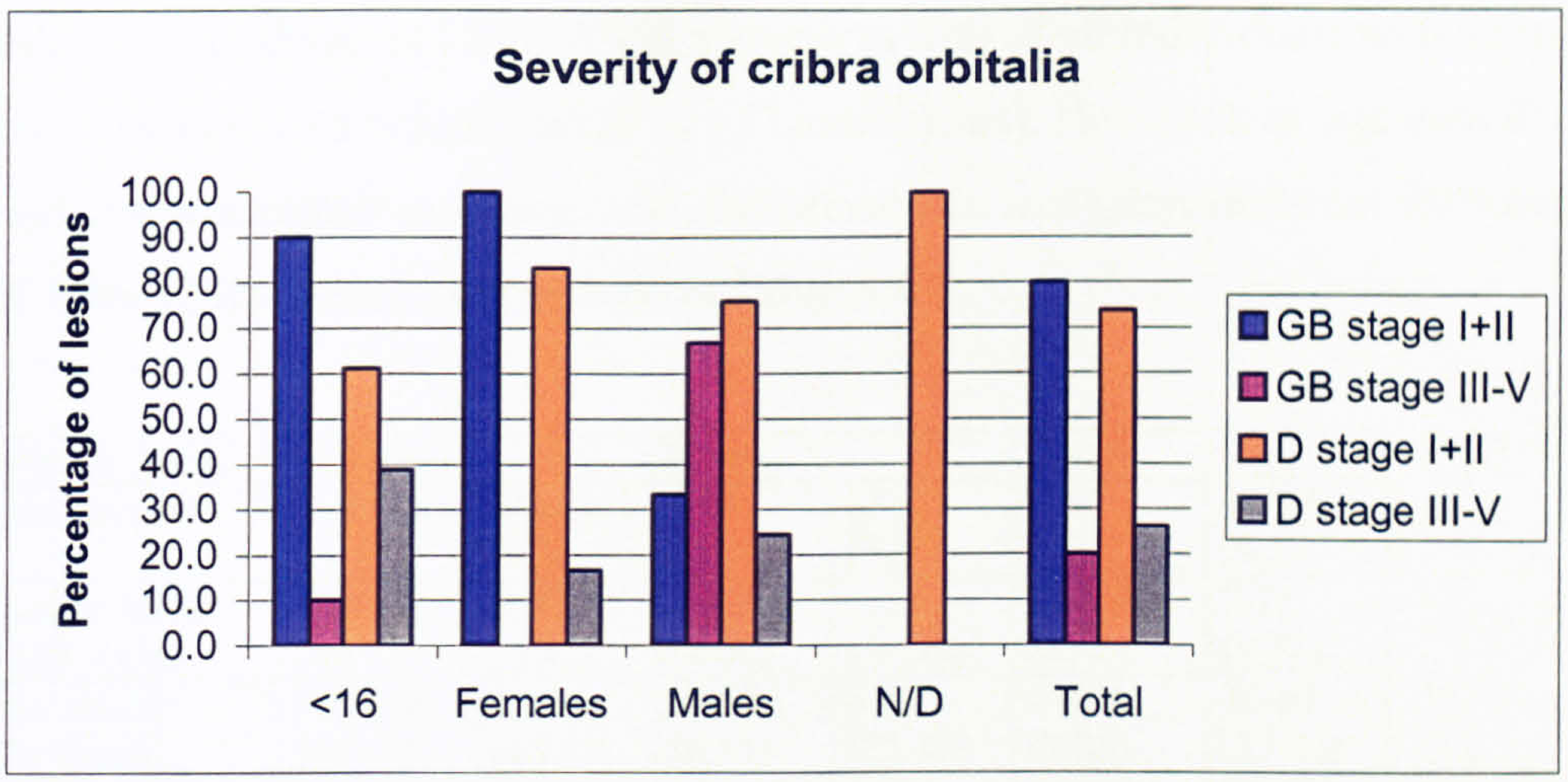


Fig. 5.8.3 Prevalence of cribra orbitalia by severity (<16=subadults below the age of 16 years, N/D=adults of undetermined sex, GB=pooled British samples, D=pooled German samples).

5.8.2 Osteoporosis

None of the British skeletons had any evidence of fractures typically associated with osteoporosis, with the exception of spinal fractures. Individuals with femoral neck fractures and Colles' fractures are listed in Appendix C8, Table 7, while all skeletons with vertebral body fractures are detailed in Appendix C8, Table 8. Four skeletons had experienced a distal radius fracture with subsequent posterior displacement of the broken end (Colles' fracture) (Table 5.8.6). However, only one of them was female (NE9-1), estimated to be young-middle aged. One of the male individuals (NU93-2) was in the same age category, while the remaining two male skeletons were estimated to be old adults. Fractures of the femoral neck were found in two individuals – one from Nusplingen was a young adult female (NU102) and the other, from the site of Pleidelsheim, was a young-middle aged male (PL71).

	Females		Males		Total	
German samples	n/N (%)	n*/N* (%)	n/N (%)	n*/N* (%)	n/N (%)	n*/N* (%)
Distal radius	1/161 (0.62)	1/58 (1.72)	3/134 (2.24)	3/49 (6.12)	4/331 (1.21)	4/120 (3.33)
Proximal femur	1/259 (0.39)	1/118 (0.85)	1/203 (0.49)	1/87 (1.15)	3/561 (0.54)	3/248 (1.21)

Table 5.8.6 Prevalence of distal radius and femoral neck fractures possibly indicative of osteoporosis for pooled German samples – bone count and individual count (n=number of bones affected, N=number of bones present, n*=number of individuals affected, N*=number of individuals present).

The overall prevalence for vertebral body fractures for the pooled British samples was less than 6.0 percent (5.69 percent, or 58 of 1,019 vertebral bodies) for all observable vertebrae T11-L5, or just above one-fifth of all individuals with their lower spine present (21.05 percent, or 28 of 133 individuals). However, as one individual could not be assigned to an age class, the prevalence is slightly different for younger and older adults, which is presented in Table 5.8.7.

Vertebral bodies	Females		Males		Total	
British samples	n/N (%)	n*/N* (%)	n/N (%)	n*/N* (%)	n/N (%)	n*/N* (%)
Younger adults (16-35 years)	2/277 (0.72)	2/37 (5.41)	12/259 (4.63)	5/35 (14.29)	14/536 (2.61)	7/72 (9.72)
Older adults (35+ years)	29/260 (11.15)	14/32 (43.75)	14/215 (6.51)	6/28 (21.43)	43/475 (9.05)	20/60 (33.33)
Total	31/537 (5.77)	16/69 (23.19)	26/474 (3.74)	11/63 (22.0)	57/1011 (5.64)	27/132 (20.46)

Table 5.8.7 Prevalence of vertebral body fractures possibly indicative of osteoporosis for pooled British samples – bone count and individual count (n=number of bones affected, N=number of bones present, n*=number of individuals affected, N*=number of individuals present).

The overall prevalence for the combined German samples was 4.22 percent, or 29 out of 688 vertebrae and almost one-fifth of all individuals had experienced one or more vertebral body fractures (19.09 percent, or 21 of 110 individuals). However, two individuals could not be included because of the missing age estimate and the adjusted frequency for younger and older adults is displayed in Table 5.8.8. Prevalence for individuals was very similar for both pooled samples with 20.45 percent and 17.59 percent affected, respectively. For both the individual count and bone count, British sites yielded slightly higher prevalence rates; 5.64 percent of all vertebrae of the lower back were affected in the British samples, while 3.54 percent of all lower back vertebrae in the German samples showed signs of fracturing.

Vertebral bodies	Females		Males		Total	
German samples	n/N (%)	n*/N* (%)	n/N (%)	n*/N* (%)	n/N (%)	n*/N* (%)
Younger adults (16-35 years)	3/255 (1.18)	3/39 (7.69)	4/164 (2.44)	3/25 (12.0)	7/419 (1.67)	6/64 (9.38)
Older adults (35+ years)	10/107 (9.35)	7/18 (38.9)	7/152 (4.61)	6/26 (23.08)	17/259 (6.56)	13/44 (29.55)
Total	13/362 (3.59)	10/57 (17.54)	11/316 (3.48)	9/51 (17.65)	24/678 (3.54)	19/108 (17.59)

Table 5.8.8 Prevalence of vertebral body fractures possibly indicative of osteoporosis for pooled German samples – bone count and individual count (n=number of bones affected, N=number

Fig. 5.8.4 demonstrates differences between the sexes for younger and older adult individuals by country. While in the pooled British and German samples younger adult males had a higher prevalence of vertebral body fractures than younger adult females, this difference was statistically not significant (British samples: χ=1.6160, p=0.2037, d.f.=1; German samples: χ=0.3327, p=0.5641, d.f.=1). A reversal of this observation was found when comparing older adult females and males; here, females had a higher frequency of vertebral body fractures. Although approaching significant levels in the British samples, this difference was not enough to be statistically significant (British samples: χ=3.3482, p=0.0673, d.f.=1; German samples: χ=1.2775, p=0.2584, d.f.=1). Only when contrasting younger and older adult females within each country, differences were of high statistical significance (British samples: χ=14.1660, p=0.0002, d.f.=1; German samples: χ=8.2856, p=0.0040, d.f.=1).

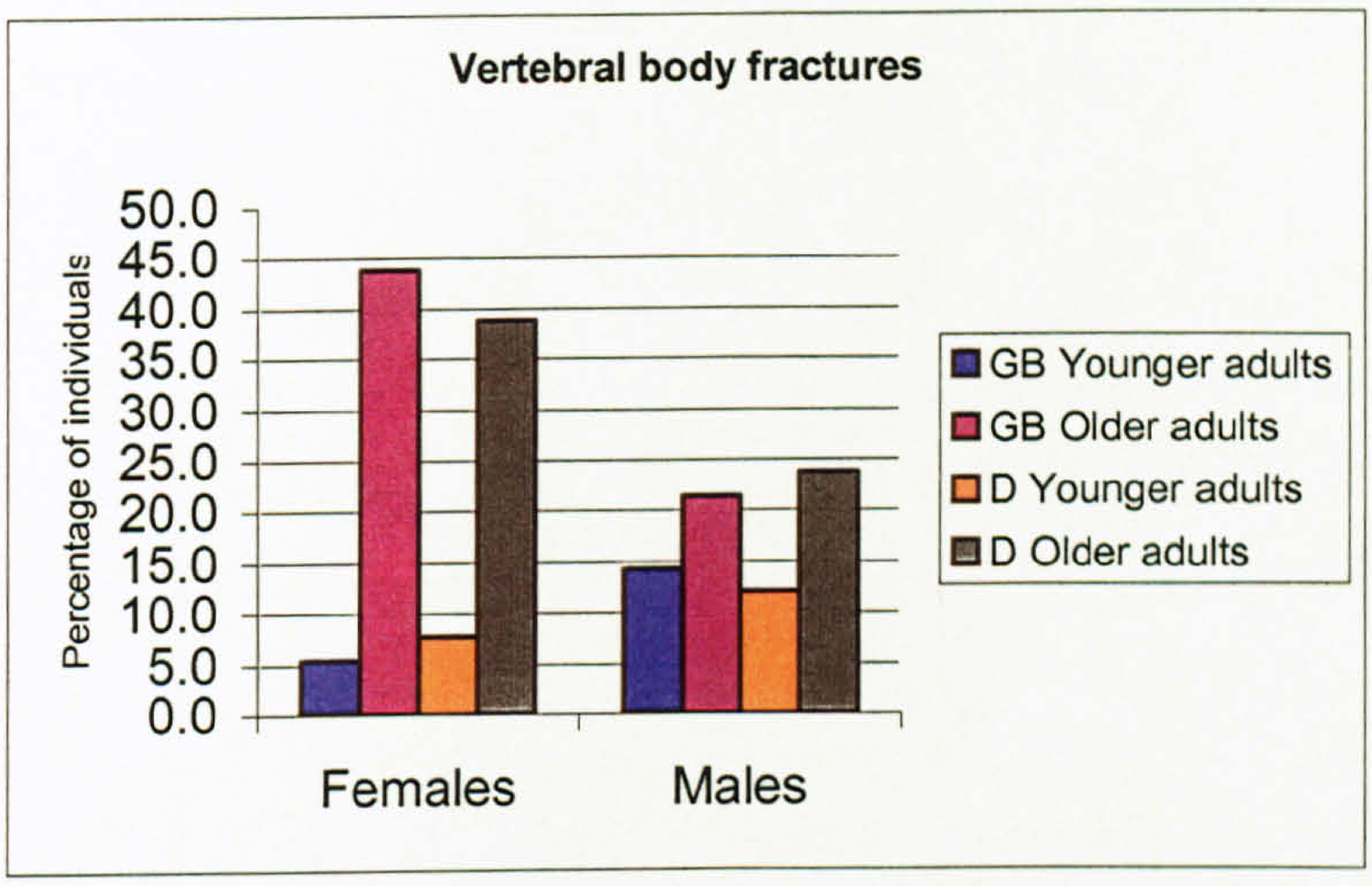


Fig. 5.8.4 Prevalence of vertebral body fractures for older and younger adults by sex and country (GB=pooled British samples, D=pooled German samples).

At this point a brief summary of the obtained results needs to be included here. A visual representation of these results can also be found on p. 346 Table 7.1. Both pooled samples showed demographic profiles with a higher frequency of female individuals. The age distribution between the samples was similar, although more German females had died in young-middle adult age. Stature was almost identical in the early medieval people of the study samples. However, German individuals had suffered from more dental pathologies, spinal osteoarthritis and cranial injuries, while extra-spinal osteoarthritis and non-cranial fractures showed similar prevalence rates. Non-specific infections, especially of the tibiae, were more prevalent in male than female individuals in both countries. In contrast, maxillary sinusitis, rib periostitis and endocranial lesion frequencies were similar between the sexes and the two pooled samples. Congenital anomalies were generally rare and no apparent differences were detectable in the study populations. Finally, cribra orbitalia, a metabolic disorder, was more often seen in the German samples and occurred predominantly in non-adult individuals. Vertebral body fractures, which may be associated with osteoporosis were more commonly found in elderly females in both countries than in males of advanced age.

The following chapter, Chapter Six, will discuss the obtained results for the prevalence and patterning of health and disease indicators. Archaeological data, textual evidence and bioarchaeological analyses conducted on other skeletal human samples will be used to examine the observed results.

CHAPTER SIX

DISCUSSION

6.1 DEMOGRAPHY

The demographic structure of skeletal populations reflects the age- and sex-specific mortality within human groups, as well as the recovery rate of skeletal elements employed for age and sex estimation. However, death does not strike randomly as the weak and frail will die first, leaving the more robust members of a population behind. Several problems arise when demographic patterns in past populations are assessed as methodological bias and sample bias will influence the results. Methodological bias arises from the imprecision of age and sex determination methods, whereas sample bias is introduced through taphonomic, recovery and mortality biases.

Results of the demographic structure were detailed in Tables 5.1.1 to 5.1.3 for the three British samples and Tables 5.1.4 to 5.1.6 for the German populations. Combining the results for the British study samples, significantly more women were present; almost half of the 315 adult individuals were female (46.67 percent, or 147 females), whereas less than one-third were male (32.38 percent, or 102 males). However, more than one-fifth of all adult individuals could not be assigned a sex (20.95 percent, or 66 adults of undetermined sex) and the actual proportion of women and men might have been different from the observed numbers if these unsexed individuals could have been included (Table 5.1.7). In contrast, most of the sexed adults could be placed into an age category (Fig. 5.1.1). Mortality within these individual age categories was similar for women and men, with most individuals dying in the young-middle adult and the middle-aged categories, while fewer females and males died as young or old adults.

A similar female predominance was found in the pooled German samples, although the difference between the number of German women and men was not statistically significant. Again, almost half of all adult skeletons were women (46.23 percent, or 190 females of 411 adult individuals), but the number of male individuals was higher than in the British samples (39.66 percent, or 163 males). Contrary to the British samples, the number of unsexed adults was lower (14.11 percent, or 58 adults of undetermined sex (Table 5.1.8). Tentatively, it might be argued that a higher proportion of unsexed British adults might have been male, but ultimately there is no proof for this. Age- and sex-related mortality in the German samples was not as evenly distributed as seen in the British populations. Young-middle aged women had a higher likelihood of dying, while more middle-aged and old adult males than females were present. However, many of the unsexed adults could not be aged precisely and the actual age distribution may have been different from the observed one (Fig. 5.1.2). Comparing the sex and age distributions between the two countries (Figs. 5.1.3 to 5.1.6) again revealed that German females preferentially died in young-middle adult age. It has been argued that women are at a higher risk of dying during their reproductive years due to "the stresses of childbearing and -rearing" (Hines, 2002: 97), resulting in a lower life expectancy for women (e.g., Bullough and Campell, 1980). However, why was there no corresponding higher female mortality in the younger age categories of British samples? Additionally, if pregnancy and birth had such a detrimental influence on women's life expectancy, why were only a few women dying in young adult age, a time when they would have been exposed to the same assumed dangers as young-middle age females? Finally, why are there relatively few non-adult individuals in both populations, where individuals under the age of 16 years were clearly under-represented? Clearly, if pregnancy and childbirth are blamed to for causing the premature deaths of women, what happened to their children? Did they all survive their mother's death and grow into adults, therefore not appearing in the skeletal record as non-adults? A general lack of non-adult individuals has been noted in early medieval cemeteries from England and Germany (Lucy, 1994; Ulrich-Bochsler, 1997). Poor preservation of non-adult bones has been cited as a possible factor for the non-survival of children's skeletal remains (e.g., Gordon and Buikstra, 1981), but in the British study samples, comparatively many infants were found (Table 5.1.9), although this was not reflected in the German samples (Table 5.1.10). Nevertheless, after the age of eight years, percentages of children were similar in both countries (Fig. 5.1.7). Even more importantly, when skeletal completeness was compared, non-adults in both pooled samples had no marked differences in the completeness of their skeletons than females and males (Figs. 5.1.8 and 5.1.9). Therefore, other factors that might have determined the observed results have to be taken into consideration. Apple Down and Norton were the only two cemeteries that were more or less entirely excavated and here, the highest proportion of non-adult skeletons was reported. Among the German sites, Nusplingen showed the lowest percentage of non-adult individuals and this was also the site which was excavated the longest ago, in the 1930s. At Nusplingen, many more graves were reported than were finally excavated and one might conclude that only burials with grave goods were retrieved, thus making it likely that children's burials which might have been less lavishly furnished, had not been recovered to the same extent as adult graves.

Inferences from the demographic structure of past populations as well as health and disease patterns are based on the assumption that the preserved skeletons represent the once living population. However, there are several reasons why this is not the case. Both, extrinsic and intrinsic factors play a crucial role in the composition of the study samples and they will be scrutinized briefly. These extrinsic aspects are independent of any of the biological features of a population and comprise of: (1) the proportion of people being buried at a certain place, (2) the proportion of those buried whose bones survive, (3) the proportion that gets excavated and (4) the proportion of those who get recovered (Waldron, 1994). Lastly (5), the effect of curation on the preservation and completeness of skeletal remains – has to be discussed.

Only in catastrophic events, such as earthquakes or volcanic eruptions, would the burial assemblage represent the once living population as everybody had the same likelihood of being buried in the same area. For instance, the inhabitants of Pompeii and Herculaneum who died during the eruption of Mount Vesuvius in 79 AD would comprise such a sample. However, this is certainly not true for the samples studied here, which represent a dead rather than a living population, where the reasons why someone was buried would have been dictated by cultural settings. Furthermore, cremation burials found at the English cemeteries were not studied and therefore another sub-sample of the once living population has been removed. Extrinsic factors that influence bone preservation include water, soil type and soil pH, in addition to climate (Henderson, 1987; Gordon and Buikstra, 1981). None of the sample sites was located in highly acidic soils that accelerate bone decomposition, but a small number of graves obviously contained no human bones. Although these may never had received a burial, the general good preservation of the retrieved skeletal material makes it unlikely that entire skeletons had vanished due to taphonomic reasons and a human vector might be considered to explain why skeletal elements, or in fact complete skeletons, were absent.

All six cemetery sites used in the current study showed varying degrees of disturbances. While in the three English samples graves were most likely to be disturbed by ploughing and/or later grave cuts, a more severe form of disturbance took place at the German cemeteries. Intentional grave robbing accounted for a large proportion of disturbed burials, which contributed to the mixing of bones, if not to their destruction. The custom of grave robbery appeared to have been widespread in early medieval southwestern Germany, judging from the archaeological evidence. Furthermore, severe punishment was imposed on anyone not observing the law against grave looting (Eckhardt, 1961). While it is not exactly known how many of the disturbed graves from Nusplingen were subject to deliberate looting, at Pleidelsheim 20 percent of all burials were robbed while at Neresheim 44 percent were found to be disturbed by thieves (Knaut, 1993; Koch, 2001). The torso and pelvic areas were especially targeted, where most of the grave goods would have been placed. By means of a hooked metal rod, further probing for valuables and weapons was conducted and finds were dragged, sometimes with the bone still attached, through the robber's trench. In some instances the robbers were detected and the culprits left in a hurry, leaving their implements behind. (Knaut, 1993). Grave robbery must clearly account for a certain, yet not quantifiable, amount of bone loss. Furthermore, the amount of unreported graves that were lost due to illegal 'excavation' cannot be quantified.

Evidently, the excavation method will dictate the proportion of skeletons retrieved. Apple Down and Norton were the only sites not excavated as a rescue measure; Apple Down was part of a larger project documenting archaeological sites in the area of the South Downs, while Norton was excavated after the chance find of the first grave (Down and Welch, 1990; Sherlock and Welch, 1992). The remaining four sites were in imminent danger of destruction by housing developments as they were all located within or nearby expanding modern settlements. This indicates that these cemeteries were certainly not excavated entirely, but even at Apple Down and Norton, their true extent was only tentatively established. In no case was the accompanying settlement detected, but it was assumed that habitations would have been in the vicinity, probably lying underneath modern towns or villages (Stork, 1990). Therefore, it was not possible to calculate the number of people living in the community to give an estimate of the settlement size.

Further loss of skeletal material can be caused by partial excavation, where skeletal elements cannot be recovered from trench boundaries. However, the proportion of partially excavated skeletons appeared to be small and much more damage was caused by deliberate and accidental disturbances. None of the excavation teams included a trained osteoarchaeologist and it can be assumed that a certain percentage of bones were missed during excavation, because they were not recognized as such. The soil from disturbed graves at Apple Down was sieved but obviously for the purpose of retaining grave goods; whether bones have been found during this procedure was not mentioned in the excavation report, and sieving was either not done or not reported at the other sites.

While storage facilities were generally good for all three British samples and study intensity low, skeletons from the German sites were curated at a teaching facility. Despite the fact that individuals were vigorously instructed to take care not to commingle, damage or misplace any of the human skeletal remains present at the Osteological Collection in Tübingen, the number of students and researchers who had access to this collection was substantial and a certain amount of bone loss can be assumed, although it cannot be quantified in a scientific way. However, one indication of this might be found when skeletal completeness of British and German samples was compared (Table 5.1.14). This preservational category was the only one of four categories (tooth and bone preservation, bone fragmentation; Tables 5.1.11 to 5.1.13), where results differed between the two countries and German samples had fewer complete skeletons.

Taking all this evidence into account, it seems likely that the observed demographic patterns rather reflect the samples' respective extrinsic preservational biases than intrinsic demographic differences due to different mortality rates. Additionally, stringent criteria for the assessment of sex and age-at-death resulted in a high number of individuals who were not sexed and/or aged.

6.2 ADULT STATURE AND NON-ADULT GROWTH PROFILES

"The final achieved height in adults can be taken as an indicator of the general state of nutrition of an individual during childhood and adolescence" (Goode *et al.*, 1993: 321). With almost identical results for mean British and German female and male adults, respectively (Table 5.2.1, Figs. 5.2.1 and 5.2.2), one might conclude that the nutritional state and general health for non-adults in both countries were similar. However, it has to be stressed that height estimates are subject to error, firstly, because of intra-observer measurement errors and secondly, because of technical measurement errors of the osteometric board. The first could be controlled by calculating the intra-observer error, which was found to be minimal, while the second could not be controlled because different osteometric boards were used throughout data collection. Furthermore, some measurements of the left side had to be substituted for right side measurements, if bones from the left side were absent. The vast majority of humans tend to have larger right arm dimensions, a phenomenon which is correlated with the dominant side of an individual (Steele, 2000). In contrast, dimensions of the left leg are larger than measurements taken on the right leg (Ruff, 1987). Consequently, substituting right for left measurements might introduce further error because of differences between the two sides.

Nevertheless, it can be expected that the discussed measurement errors would appear to act on all study samples, thus levelling out discrepancies. In fact, mean height for females and males, respectively, and height ranges were similar in both countries and any variation could have been caused by the inherent standard deviation. Waldron (1998) has noticed that comparisons of population-based adult height estimations are subject to severe errors, at least for male individuals when using length from any other bone than the femur. However, in both study samples, more than half of all measurements were taken on the femur and tibia, which provide the lowest standard deviation (Tables 5.2.2 and 5.2.3). Therefore, results should be comparable and the observed similarities might be real.

Fluctuations in mean adult height over time have been used to assess possible adaptations to adverse environmental conditions, assuming that reduced stature indicates generalized stress in the pre-adult years (e.g., Roberts and Cox, 2003). Early medieval English individuals from the study samples were of similar height compared to their modern counterparts; in 1979, British males had a mean height of 175.0 cm (5'9") (Roberts and Manchester, 1995: Table 2.1), which means they were on average one centimetre taller than the British men from the three study sites, although early medieval and modern British women's height was the same at 163 cm (5'4 ½") (Floud *et al.*, 1990). Statistical data on German stature in 2003 yielded slightly higher measurements – on average women were 165.0 cm (5'5") and men 177.0 cm (5'10"); therefore early medieval German women were 2.5 cm (1") shorter than their modern counterparts and modern German men had also gained approximately 2.5 cm (1") (Statistisches Bundesamt, 2003). However, since stature for modern living people is usually obtained by direct measurement, living stature and stature calculated from regression formulae may not be directly comparable. In addition, even stature assessments of living people do not always achieve great accuracy. Krogman and İşcan (1986) reported that height could vary from 0.75 to 1.25 inches when measuring the same group of individuals in the morning and again at the end of the day.

In modern studies, "short adult statures are associated with reduced work capacity and, in women, with obstetric complications and small birth weights of offspring" (Roche and Sun, 2003: 195). There is also a positive correlation between short stature and the development of Alzheimer's disease (Abbott *et al.*, 1998). On the other hand, tall stature is correlated with certain types of malignant tumours, such as breast and colon cancer (Albanes *et al.*, 1988). However, while these findings should be borne in mind, they would be hard to confirm in skeletal human remains. Only two individuals, a young adult female and a young-middle adult male from Pleidelsheim (PL16A and PL102) were of unusually short stature. Using the combined measurements of the femur and tibia, the woman was only 145.5 cm tall (4'9''), leaving her approximately 5 cm (2'') short of the minimum range found at the other two German sites (Fig. 5.2.3). Even when including the standard deviation of 3.55 cm, she was still shorter than other females from the study samples. Although placed within the young adult age class, growth had already ceased, since all long bone epiphyses were closed; delayed maturation was therefore not a likely reason for her short stature. However, she displayed two conditions traditionally associated with non-specific childhood stress. Both cribra orbitalia and enamel hypoplasia were present in this individual, hinting at some growth disturbance experienced in childhood. In contrast, the short young-middle adult male from the same site, who was 157.02 cm tall (5'2'') calculated from combined measurements of the femur and tibia, did not display cribra orbitalia, but only enamel hypoplasia.

Despite these two examples from the German site of Pleidelsheim, the minimum and maximum ranges for adult height were comparable between the study samples. Since possible stunting would have occurred in childhood, non-adult femoral length for the two countries was plotted against mean dental calcification age and compared with each other (Table 5.2.4 and Fig. 5.2.5). Some discrepancies were observed, especially in the ages between five and seven years. However, the number of individuals on which observations could be made was low and had to be based on estimates in some age classes. For this reason, the reliability of these results has to be questioned.

6.3 Dental disease

6.3.1 Dental caries

Dental caries – deciduous teeth

In both combined samples deciduous caries prevalence was low with approximately 2.5 percent of all teeth affected. However, this observed prevalence rate must be regarded as an underestimate of actual caries prevalence, because an unknown number of deciduous teeth lost upon eruption of the permanent dentition might have displayed carious cavities. From the 30 British individuals, only 349 deciduous teeth (58.17 percent of 600 possible teeth) were present and the 53 German subadults yielded 475 deciduous teeth (44.81 percent of 1,060 possible teeth). The numbers of possible teeth can only be seen as approximations since deciduous teeth are replaced by their permanent successor over a considerable time period and therefore not all individuals would have had their complete set of deciduous teeth present at their time of death.

While dental caries of the deciduous dentition is a major health problem in modern western societies, archaeological data on non-adult caries prevalence is infrequently reported (Schulz, 1992; Steinbach, 1996). In a modern study, Naujoks (1987) reported a dramatic increase in deciduous tooth caries among school children from the German city of Hamburg. Here, 70 percent of the three-year olds and 85.2 percent of the six-year old children had caries. In an archaeological context, Stroud (1993) found 6 of 40 late medieval children (15.0 percent) from St Andrew, Fishergate, York had suffered from deciduous tooth caries, a percentage which corresponds reasonably well with the observed frequencies of 16.67 percent for the early medieval British samples and 11.32 percent for the German individuals. Deciduous maxillary teeth in the later medieval population from York were likely to be affected more often than the mandibular dentition, an observation which was also made in the present study. Stroud (1993) noted that 7.7 percent of maxillary and only 1.0 percent of mandibular teeth had caries. This results in a total deciduous caries prevalence for the Fishergate sample of 4.35 percent, a figure almost twice as high as the 2.5 percent observed for the early medieval populations in the present study. One of the reasons why the percentage of affected individuals is very similar between early and later medieval populations in England, while the percentage of teeth affected is higher in the later medieval period, might be due to the lower percentage of deciduous teeth preserved at York. Here, only 39 percent of all possible teeth were present. However, this number of available teeth seems to be even lower, because in the final analysis only 40 children were considered, while the tooth count was applied to 65 individuals (Stroud, 1993: 199). Despite these discrepancies, the lower caries frequencies by tooth number found in the early medieval samples in the present analysis might also be explained by the lack of readily available sugar in their diet. The early medieval diet consisted mainly of cereals, meat and dairy products, and the only available sweetening agent would have been honey (Hagen, 1992; 1995). However, it remains unclear to what extent young children were fed the same foodstuffs as adults.

Evidence from another British site suggests even lower prevalence rates than in the present study. Mays (1996b), in his skeletal report of the Anglo-Saxon cemetery of Empingham II, Rutland, found a very low percentage of deciduous teeth affected by caries (0.9 percent, or 2 of 222 teeth). However, the actual number of affected individuals is not stated. In contrast, Schulz (1992), reporting on a large skeletal sample spanning the historic period of California, found a high prevalence of deciduous caries – 30.0 percent of non-adult individuals (24 of 80 individuals) or 6.15 percent of deciduous teeth (60 of 976 erupted teeth) had evidence of dental caries. This was attributed to a high dependence on carbohydrate-rich food, especially acorns.

The data on deciduous caries experience for the six early medieval study samples suggests a diet low in carbohydrates or other cariogenic foodstuffs, especially when compared to later medieval and modern prevalence rates. However, the possibility that affected primary teeth were lost during life, as a consequence of carious attack has to be considered. The absence of tooth defects (Turner teeth) in any of the analysed permanent teeth suggests that the low caries rate was not caused by post-mortem deciduous tooth loss. However, the occurrence of Turner teeth relies on the presence of periapical lesions presumably caused by pulp exposure due to caries (Schulz, 1992). Perhaps carious primary teeth were shed naturally during their replacement by the secondary dentition before this more severe development took place and consequently the lack of Turner teeth might not be indicative of a low caries prevalence in the deciduous dentition.

O'Sullivan and colleagues (1993) collated data on deciduous tooth caries from 221 English children dating from pre-Roman to late medieval times, finding that molars were more often affected than any other tooth class. O'Sullivan and co-workers (1993) reported a similar prevalence pattern for deciduous caries as seen for permanent teeth from other British studies (Moore and Corbett, 1971; 1973; 1975): low rates in pre-

Roman and early medieval times, a relatively high rate in the Romano-British period and a sharp rise in the thirteenth century.

Dental caries – permanent teeth

Traditionally, differences in caries prevalence between populations are attributed to differences in their subsistence strategies, with hunter-gatherers having suffered less from carious lesions than agriculturalists (Larsen, 1997). In the current study, explanations other than subsistence have to be considered for the noticeable differences between the study samples. Foodstuffs derived from cultivated crops and domesticated animals provided the main proportion of the diet, although remains from wild animals and plants were recovered from settlement sites in both countries (Hagen, 1995).

Some variation in caries prevalence between the samples occurred in the two countries, for both the number of affected individuals and the number of affected teeth (Tables 5.3.4 and 5.3.6). Differences in caries prevalence proved to be statistically significant with almost half of all German individuals in the pooled sample having experienced caries, while less than one-third of the British skeletons had evidence of the disease (Table 5.3.5). With regard to the number of carious teeth, more than twice as many teeth from German samples had carious cavities (Table 5.3.7). Furthermore, how do the present findings compare to caries frequencies observed for other British and German samples from a similar time period? A large amount of data has been collated for British sites dating to the early medieval period (Roberts and Cox, 2003). A total of 50 skeletal samples (including the three sites used in the present analysis) provided information on dental caries experience. Caries affected 5.3 percent of all individuals (375 of 7,122 individuals). Compared to the overall frequency of 28.29 percent (82 of 290 individuals) calculated for the three British samples discussed here, this seems to be an extraordinarily low prevalence. However, these two sets of data are not comparable, since the first included all individuals present regardless of whether they had any teeth preserved or not, while the latter only included individuals with at least one tooth present. For German sites, an average caries prevalence of 60-70 percent for individuals has been reported (Wahl *et al.*, 1998), which is slightly higher than the 47.09 percent (194 of 412 individuals) found in the present analysis. However, it is not known on how many sites, individuals or teeth the study by Wahl and co-workers is based, nor do they mention which criteria were used to diagnose dental caries. Roberts and Cox (2003) also presented data by number of teeth examined and their absolute caries frequency for early medieval British samples was 4.2 percent (1,636 of 38,911 teeth), which compares reasonably well with the 3.13 percent (169 of 5,405 teeth from 36 sites) recorded for the three British samples in this study. Wahl and colleagues (1998) reported that 10-15 percent of German teeth had cavities. This rate lies well above the 6.88 percent (416 of 6,047 teeth) observed in the three German study samples but, again, it is not known how many teeth contributed to the study, nor is it mentioned whether non-adults were included. In the light of these difficulties with data comparison between different researchers, the observed differences might not be meaningful.

Diet has been the single most important culprit in the development of dental caries, in the past and in modern times. Especially carbohydrate-rich food components such as cereals would have provided nutrients for humans as well as their oral bacteria. However, as a diet based on cereal crops can be assumed to have been eaten in both countries, this would not explain the marked difference in caries prevalence. There is no easy way of quantifying to which extent specific food groups were consumed in the early medieval period. However, isotopic analysis might provide some insights. In the absence of any isotopic studies performed on the study samples, with the exception of Neresheim, other data might at least give some approximations. At Berinsfield, Oxfordshire, a protein-rich diet was prevalent, although it was not ascertained whether proteins derived from meat or dairy products (Privat *et al.*, 2002). In a wide-ranging stable isotope study of early medieval skeletal human remains from southwestern Germany, a mixed diet consisting of carbohydrates as well as protein was detected (Schutkowski and Herrmann, 1996; Schutkowski, 2000). However, it is probably stretching the data too far to conclude that the early medieval British populations 'feasted' largely on animal products, while their Continental neighbours had to make do with a more balanced combination of proteins and carbohydrates, rendering them more susceptible to dental caries. The variation of dental caries prevalence within the British samples attests to some differences in their exposure to cariogenic factors. Again, diet was possibly one of the main causes, but caries is a multi-factorial disease and other variables might have influenced these results. Among these, age and sex are certainly two important aspects, which have to be discussed. However, while the influence of age on dental caries prevalence is relatively straightforward, sex-related caries prevalence is more ambiguous. Although in a modern context females are more likely to suffer from dental caries, this might rather be influenced by cultural rather than biological factors, and the archaeological data is less clear-cut when it comes to determining which of the two sexes experienced more dental caries. However, when differences in caries prevalence between women and men are present in archaeological samples, they are usually explained by differential access to certain foodstuffs. Hypothesizing that men had better access to high status food such as meat, which is cariostatic, their caries prevalence should be lower than that of contemporary females. Although among the British samples, women had more caries than men, this difference was statistically insignificant and therefore might have occurred by chance. Nevertheless, with the exception of Norton, females at Apple Down and Castledyke South experienced more caries than males. The opposite was observed for the German samples. Here, only women from Neresheim outnumbered their men in caries experience; at Nusplingen and Pleidelsheim, the male part of the population was more often affected. Nevertheless, when pooling data for the three German sites, males only had insignificantly more caries than females. However, there was a large proportion of adult individuals to whom no sex could be assigned and the proportion of female and male caries prevalence might have been different if the previously unsexed subgroup had been included. However, when it comes to sex determination in skeletal assemblages, there is usually a bias towards the male sex since male skeletons are more robust and therefore are not only more likely to survive in the burial environment but are also potentially more easily to identify by the bioarchaeologist (Weiss, 1972; Walker *et al.*, 1988). In the light of this, a larger proportion of unsexed adults might have been female and the proportions of female and male individuals with dental caries would have been skewed more towards the female sex. On the other hand, if the observed proportions reflect the true prevalence between the sexes then some other factors have to be considered. If diet had such a crucial impact on sex-related caries prevalence, one further aspect has to be investigated, specifically the influence of drink. Throughout history and probably prehistory as well, the consumption of fermented drinks is attested and alcoholic beverages were certainly well established in the early medieval period (Dietler, 1990). In the first century AD, Tacitus remarked that Germanic tribes consumed vast amounts of a wine-like drink brewed from barley or wheat (Fuhrmann, 1971). Salvianus, a Gallic author living in the fifth century AD, described the Alamanni tribes, who inhabited southwestern Germany as very much inclined towards alcohol (Dirlmeier and Gottlieb, 1978). For early medieval Britain, numerous references to wine, beer, ale and presumably cider are known (Hagen, 1995). Alcoholic drinks are not only intoxicating; they also contain a high amount of sugar, which in itself is highly cariogenic. However, alcohol-derived sugar as a factor of cariogenicity might not be the only reason for a higher caries prevalence observed in the German samples.

In the twentieth century, scientists have recognized the importance of fluoride in their battle against dental caries, which resulted in a number of fluoridation projects, for example in parts of the UK (Jackson *et al.*, 1975; Gray and Davies-Slowik, 2001). While modern data on local fluoride levels in the soil and water are not necessarily the same as they were in the early medieval period, at least an approximation might be obtained. In Britain, sub-optimal levels of 0.5 ppm (parts per million) are the most frequent, but in some regions, higher values are recorded. One of these areas with optimal fluoride levels is in the northeast of Britain and here, especially in north Cleveland, where high natural fluoride concentrations of 1.1-1.5 mg/l (milligram per litre) occur in water (Drinking Water Inspectorate, 2002). One of the study samples, Norton, lies within this fluoride-rich area, and at this site the lowest caries prevalence of all study samples was reported. In contrast, Germany is described as a fluoride-deprived country, where fluoride levels are far below optimum in all regions of the country, although for legal reasons, fluoridation programmes were never established (van Steenkiste, 1995). Natural fluoride contents of drinking water from Baden-Württemberg do not exceed 0.05-0.08 mg/l (Energie Baden-Württemberg, 2004). The lack of fluoride may have contributed to the higher caries prevalence rates found for the German sites. Furthermore, saltwater fish contain high amounts of fluoride and would have been potentially available to early medieval British population, but not to the inland inhabitants of southwestern Germany during this time period. However, fish consumption was not confirmed for any of the British sites analysed here. Additionally, fish bone is more fluoride-rich than meat and therefore, if consumed, would not appear in the archaeological record.

Despite all these contrasts between British and German teeth with regard to caries prevalence, there are also certain similarities. In both countries, anterior teeth had fewer caries compared to the posterior dentition (Table 5.3.8, Fig. 5.3.2). This is a common observation, which is best explained by tooth morphology. Premolars and molars are more likely to display carious lesions because food gets more easily trapped within fissures of the occlusal surface, leaving these sites susceptible to acidic demineralization. Likewise, bacterial build up between posterior teeth is more noticeable than between neighbouring anterior teeth. However, while caries prevalence in the British samples increased from the first to third molars, more variation was seen in the German samples. There seem to be no obvious biological explanation for this observation and the same preservational factors were found in the British samples. The first permanent tooth to erupt is the first molar and therefore it has been argued that this tooth was the most at risk to develop caries since it was the longest exposed to cariogenic influences. However, in none of the pooled samples was first molar prevalence higher than in second or third molars. Furthermore, third molars in both countries were less often preserved than other posterior teeth and, consequently, third molar frequency should have been high in both countries, and not only in German samples. Radloff (1973), in a study of dental caries in an early medieval skeletal population from Eltville, Rheingaukreis (Germany) found comparable results. The overall caries prevalence in this sample was 10.9 percent (353 of 3,231 teeth), which is slightly higher than in the German samples in the present study. The teeth most often affected in his analysis were the second molars (19.0 percent, or 79 of 415 teeth), a comparable observation to the present study. However, site specificity of carious attack may be influenced by individual oral anatomy and physiology. Differences in the size and shape of the jaws will affect the size and shape of the overlying muscles and the mucosa covering them. Within these, lie the glands responsible for saliva production. Saliva composition and rate and direction of flow, influence the clearing away of substances such as carbohydrates, adhering to teeth. As relatively closed communities might develop similar facial characteristics and dimensions, they might also develop similar patterns of caries lesions (Weatherall *et al.*, 1989).

Cavity location was very similar between the two countries, with the vast majority of lesions located on the cemento-enamel junction (Fig. 5.3.3). In particular, interproximal areas between neighbouring teeth were at risk and this caries location is often associated with a lack in dental hygiene (Hollack and Kunter, 2001). Kerr (2000) observed a positive relationship between dental wear and caries location on teeth. Before the consumption of soft and refined foods was established in the seventeenth century, dental attrition was severe enough to remove pits and fissures of the occlusal surface, in which bacteria could have developed. However, for the present study, dental attrition was used as an ageing criterion and to avoid a circular argument could therefore not be used to assess its influence on caries location.

Lastly, a steady increase in age-related caries prevalence was observed for pooled British samples culminating in the old adult age (Table 5.3.9 and Fig. 5.3.4). German individuals reached their peak in caries frequency at a much earlier age, in the young-middle adult category and thereafter, prevalence remained slightly below that level. In skeletal populations, usually caries prevalence increases with advancing age, but often drops in the oldest age category, because of a parallel increase in ante-mortem tooth loss especially targeting carious teeth. There was a small drop in prevalence in the two older age categories for the German sample and this might have been caused by the effect of advanced tooth loss during life. In fact, AMTL was highest in middle-aged and old adults (Fig. 5.3.8). However, the same age-related increase in ante-mortem tooth loss did not lead to a similar result in the British samples. As there is no way to ascertain the reasons why teeth were lost ante-mortem – caries, periapical lesions or through periodontal disease – the observed pattern cannot be explained adequately. On the other hand, none of the differences in caries prevalence between middle-aged and old adults was statistically significant, indicating that these dissimilarities were minor.

6.3.2 Dental calculus – deciduous and permanent teeth

As it was not feasible to investigate dental calculus frequencies by affected teeth, data was only present for affected individuals. Similar to deciduous tooth caries, dental calculus was more prevalent in British non-adults. However, this difference did not prove to be statistically significant, with one-quarter of British children and 15.09 percent of German non-adults being affected (Table 5.3.10). Usually, in archaeological human samples an inverse relationship between caries and calculus prevalence rates is observed, although this was not the case in the two study samples with regard to the primary dentition. However, the percentage of dental calculus deposited even on the teeth of the youngest individuals indicates a lack of oral hygiene from a very young age onwards.

The same observation was made with regard to calculus prevalence of permanent teeth in the non-adult age category. British individuals below the age of 16 years had a higher calculus prevalence than non-adults from the German samples and in this instance, the difference proved statistically significant. However, variation in adult calculus frequency, between the pooled samples as well as between the sexes was not significant. Oral hygiene was not a priority, in neither early medieval Britain nor Germany, and almost three-quarter of the populations displayed dental calculus (e.g., Plate I, 1). As there were no noticeable differences between calculus frequencies in women and men, it can be concluded that a general lack of oral plaque removal prevailed. Since diet, and in particular proteins, seem to influence the build-up of calculus deposits, there was no sex-related difference in terms of the proportion of protein consumed.

However, it has to be stressed that calculus becomes easily removed from the dentition and the observed prevalence rates are likely to be underestimates of the true frequency. This unintentional loss of calculus deposits was probably more prevalent among teeth from the German samples, since the three study samples were curated in a teaching collection. Additionally, a number of dissertation projects focussing on dental disease were conducted. In contrast, the three British samples were less frequently subjected to analysis and their calculus deposits were probably less likely to become dislodged.

No textual evidence from the early medieval period indicates oral hygiene, but in the Roman period the use of mouthwashes made, for instance, from urine, were known (Thornton, 1991). A mixture of meerschaum, salt and burnt oysters and snails ground together with honey was recommended by Avicenna (980-1037) to clean one's teeth and numerous other recipes of dentrifice from earlier and later times are known (Freeth, 2002). However, without microscopic investigation for scratches on teeth caused by abrasive agents in such dentrifices, their presence cannot be established. Furthermore, non-abrasive objects, for example twigs, sponges or even one's own finger, could have been used in tooth cleaning and these would have not left traces.

6.3.3 Periapical lesions and pulp exposure

Since the development of periapical lesions is ultimately linked to the presence of dental caries, it is not surprising that the overall prevalence of this condition was significantly higher in the pooled German samples (Table 5.3.14, Fig. 5.3.5 and Plate I, 2). British frequencies of periapical lesions corresponded well with dental caries prevalence. At Apple Down, prevalence of periapical lesions and dental caries was the highest, followed by Castledyke South and Norton where a low prevalence of both conditions was observed (Table 5.3.13). Similar to dental caries, prevalence of periapical lesions showed less variation among the German samples. One further similarity was that no differences between female and male prevalence rates were found, neither for periapical lesions, nor for dental caries. Periodontal disease, too, might be responsible for the formation of periapical lesions and again German individuals had suffered more from this disease than their British counterparts.

However, differences in periapical lesion frequency between the two countries were less clear-cut with regard to the number of observable tooth positions (Tables 5.3.15 and

5.3.16). This was due to the fact that the mean number of periapical lesions per affected individual was higher in the pooled British samples; British individuals had 1.9 lesions per individual (57 lesions in 30 individuals), while German individuals had an average of 1.47 periapical lesions (109 lesions in 74 individuals). Alternatively, expressed in a different way, fewer British individuals had more periapical lesions, while more German skeletons had fewer lesions. The overall prevalence of 1.16 percent (57 of 4,928 tooth positions) for the pooled British samples appears low in comparison with the 2.75 percent (1,149 of 41,737 tooth positions) reported for early medieval British samples (Roberts and Cox, 2003). However, in their study samples size was much larger with 31 sites being included, ranging in prevalence from 0.2 to 9.1 percent. Nevertheless, frequencies observed in the current study fall within this range, but at the lower end. No comparable compilation of data on dental disease exists for sites from early medieval Germany.

Despite the differences in prevalence between the British and German samples, an age-related increase in periapical lesion prevalence was observed for both, but even from an early age frequencies were higher in the German samples (Table 5.3.17 and Fig. 5.3.17). However, the age of lesion development cannot be determined, because a person might have lived a considerable amount of time after a lesion was formed. Nevertheless, it demonstrates the accumulating effect of the disease process. Once formed, periapical lesions do not become remodelled again and with advancing age, the number of lesions also increases.

Unsurprisingly, periapical lesions and pulp exposure followed a similar trend, since the first frequently results as a consequence of the latter. Sites with a high frequency of pulp exposure also had a high prevalence of periapical lesions, in relation to affected individuals as well as affected teeth and tooth positions. With regard to affected tooth position, no clear tendency was present when periapical lesions were regarded by themselves (Table 5.3.18 and Fig. 5.3.7). However, when compared to specific teeth affected by pulp exposure, a reasonably good fit between the two conditions was noted (Figs. 5.3.8 and 5.3.9).

6.3.4 Ante-mortem tooth loss (AMTL)

Ante-mortem tooth loss (AMTL) can be the result of several factors, such as advanced dental caries or periodontal disease, as well as high attrition and loss due to trauma. In addition, vitamin C deficiency (scurvy) can also lead to the premature loss of teeth.

The same trend as in the previously discussed dental diseases was noted with regard to AMTL. Overall, prevalence was significantly lower in the British samples (Table. 5.3.25). Nevertheless, variation within the British samples was noted; as for dental caries and periapical lesions, individuals at Apple Down displayed AMTL more often than skeletons from Castledyke South and prevalence was lowest at Norton with regard to affected individuals. In contrast, in the German samples AMTL frequencies were uniformly high (Table 5.3.24 and Plate I, 3).

While the true prevalence of 7.16 percent (353 of 4,928 tooth positions) for the three British study samples was close to the rate of 8.0 percent (3,330 of 41,400 tooth sockets from 30 sites) observed by Roberts and Cox (2003), with regard to the number of affected individuals, there was an apparent discrepancy, since a total of 31.9 percent (67 of 210 individuals) displayed ante-mortem tooth loss in the current study, but only 3.1 percent (224 of 7,122 individuals) were affected in their pooled British sample. No large-scale investigation into ante-mortem tooth loss was available for German samples. However, Radloff (1973) found an overall AMTL prevalence of 17.2 percent of affected tooth sockets at the site of Eltville, Rheingaukreis, but the actual number on which this percentage is based is not given. More detailed data on ante-mortem tooth loss is available from a recent skeletal report by Hollack and Kunter (2001). The prevalence of AMTL in the early medieval population from Eichstetten am Kaiserstuhl (Baden-Württemberg, Germany) was 25.4 percent, which appears to be very high compared to the present analysis. However, this result has to be treated with caution, since prevalence was calculated by dividing the number of available teeth (N=2,932) and not the number of available tooth sockets by the number of teeth lost ante-mortem (n=745). A high number of teeth lost ante-mortem was also reported for a sixth to seventh-century AD cemetery from Doubs, France, although no statistical data was available for the 572 excavated skeletons (Urlacher *et al.*, 1998). The authors concluded that the "low number of carious teeth in conjunction with the high amount of ante-mortem tooth loss is probably due to the extraction of diseased teeth" (Urlacher *et al.*, 1998: 46). However, there is no archaeological or textual evidence that dentistry was practised during the early medieval period, although numerous finds of dentists' instruments and medical treaties on tooth extraction have survived from the Roman period (Koenig, 1982). Nevertheless, even the Roman dentists viewed tooth extraction as a last resort, since the dangers associated with the forceful extraction of a tooth from the alveolar socket were well known (Kollesch and Nickel, 1994). For instance, in Britain tooth extraction became widespread only in the fourteenth century, when the craft of tooth drawing was included in the first memorandum of the Company of Barber Surgeons in 1376 (Nettleton, 1992). Remedies for toothache are mentioned in Bald's leech book, where chewing of pepper or henbane roots in wine and vinegar was recommended (Cameron, 1993).

Age clearly seems to be a factor correlated with AMTL and in both pooled study samples; an increase in tooth loss during life has been noted with advancing age (Table 5.3.28 and Fig. 5.3.10). This can be readily explained by the cumulative effect of dental diseases enhancing ante-mortem tooth loss. However, like all dental diseases, the actual age at which a lesion developed cannot be determined. Furthermore, continuous tooth eruption in response to attrition increases with age and consequently teeth are being exfoliated preferentially in older age categories (Kerr, 2000). As continuous eruption occurs mainly on the posterior teeth, these would be the teeth preferentially lost during life. However, posterior teeth are also more prone to develop carious cavities, as well as being more susceptible to periodontal disease and, ultimately, the reason for ante-mortem tooth loss cannot be assessed by examining the pattern of teeth lost. In both study samples posterior tooth loss outnumbered teeth lost from the anterior dentition (Table 5.3.29 and Fig. 5.3.11). Canines had a consistently low prevalence, which can be explained by the tooth's long root anchoring it securely into its alveolar socket. First and second incisors were affected by AMTL and the influence of dental trauma has to be considered as a causative factor. Usually, anterior teeth are more prone to accidental or intentional fractures during a fall or while being hit in the face than posterior teeth. Normally this would result in a broken tooth crown or loss of the entire tooth. Nevertheless, only one case of ante-mortem tooth chipping was found in a female from the German site of Neresheim (NE30). Her mandibular right canine had lost a small portion of the crown, and the break was subsequently covered by calculus. Therefore, judging from the present evidence, tooth trauma occurred very infrequently and not many anterior teeth have been lost because of trauma. However, ante-mortem dental trauma may be difficult to identify in skeletal remains due to the flaking off of tooth enamel in the burial environment, post-mortem loss of teeth, or tooth damage during excavation and curation (Alvrus, 1997).

6.3.5 Periodontal disease

Periodontal disease is a common dental condition today, affecting 10-15 percent of individuals in all populations, and those will lose half their teeth by the age of 50. However, aetiological factors are likely to have changed over time and in modern groups a link between periodontal disease and obesity has been demonstrated (Ritchie and Kinane, 2003). A large number of individuals were affected in the study samples (Table 5.3.30). Overall prevalence rates were significantly higher in the pooled German samples, where almost three-quarters of all adult individuals were affected by the disease; in contrast close to half of all adult skeletons from British samples displayed periodontal disease. Prevalence between women and men was similar in both countries (Table 5.3.31). The same trend of higher frequencies for German samples was observed with regard to affected tooth sockets, with the exception of Neresheim, where a considerably lower prevalence was found (Tables 5.3.32). However, for pooled German samples, the rate of periodontal disease was higher compared to British samples (Table 5.3.33).

The development of periodontal disease is governed by multiple factors such as dental attrition and oral hygiene. Scurvy might also lead to ante-mortem tooth loss, or in less advanced stages to pitting and new bone formation due to haemorrhaging into the gingival tissues, especially in children. Although one 12-14 year-old subadult from Neresheim (NE41) had lost two teeth during life, there was no evidence of inflammation or new bone formation on the alveolar bone making a diagnosis of scurvy unlikely. In general, an increase in prevalence of periodontal disease was noted with advancing age, and this phenomenon was observed in both pooled samples (Table 5.3.34 and Fig. 5.3.12). In modern populations, periodontal disease becomes more prevalent in the fourth decade of a person's life and predominantly affects the posterior dentition (Kissane, 1990). A similar increase in prevalence starting in the young-middle adult age category was present in the study samples, and this is probably caused by the accumulative effects of the neglect of oral hygiene and the subsequent development of dental calculus. The seemingly paradoxical lower calculus prevalence observed in German individuals was most likely influenced by post-mortem loss of calculus deposits. Furthermore, indirect evidence for the presence of periodontal disease might be found in British medical texts of the eleventh century AD, whose origins might have been even earlier. Toothache and sore gums were treated with globe thistle and lousewort, while great water dock was applied to strengthen loose teeth (van Arsdall, 2002). Nevertheless, these herbal remedies were probably not very effective. Interestingly, successful treatment of periodontal disease in the form of cauterization was already proposed in the first century AD by the Roman medical writer Celsus (Kollesch and Nickel, 1994). However, it is not known whether this was practised in the early medieval period.

6.3.6 Enamel hypoplasia – deciduous and permanent teeth

The low frequency of enamel hypoplasia found in deciduous teeth from German sites, for both individuals and teeth observable, attests to a low pre-natal stress exposure in these populations. However, since no enamel defects on deciduous teeth were observed at the British sites, it can be assumed that maternal stress levels during intrauterine development were even lower or were not severe enough to disrupt deciduous tooth enamel formation. Lewis (2002) found a similar low prevalence rate in one of her later medieval samples. At the urban site of St Helen-on-the-Walls, York, 2 percent of deciduous teeth showed enamel hypoplasia, while none of the two rural sites, one from the early, the other from the later medieval period, had any signs of enamel defects.

After birth, disruption of enamel formation was observed in all of the study samples, where they became manifest on permanent teeth (Tables 5.3.36-5.3.39, Plate I, 4). No differences between female and male prevalence rates were present and therefore it may be concluded that no differences in childhood stress episodes between boys and girls occurred. However, since many different childhood diseases as well as nutritional deficiencies may lead to the formation of enamel hypoplasia, no conclusion should be drawn on the factors causing the defects. Compared to other British samples from a similar time period collected by Roberts and Cox (2003), prevalence rates for affected individuals were similar, 18.8 percent of all skeletons were affected in their study, compared to 15.7 percent in the present analysis. In Germany, Kreutz and co-workers (2000) found an enamel hypoplasia prevalence of 42.0 percent in an early medieval population from Straubing, Bavaria. However, care should be taken when comparing enamel hypoplasia frequencies, since no universal consensus exists for when a defect should be scored as present or absent (Hillson, 2000).

Most enamel growth disturbances in both, the British and the German samples, had occurred between the age of 1.5 and 2 years (Fig. 5.3.14). However, the rise in enamel defects started in the previous age band of 1.0-1.5 years, an observation that has previously been made by Lewis (2002). She attributes these findings to the fact that nutritional and immunological effects of breast milk diminish after the first six months of life and only food consisting of nutritious and pathogen-free properties can successfully prevent what is known as weaning stress. While food supplementation might be successful for a certain amount of time, children in both study samples had succumbed to nutritional or pathological stressors after some time. A similar scenario was proposed by Moggi-Cecchi and co-workers (1994), who noticed a high rate of enamel hypoplasia formation between 1.5 and 3.5 years in their sample of nineteenth-century children from Florence, Italy. They argued that weaning was not an abrupt but rather a prolonged process, gradually introducing children to a new diet. Consequently, stress was not a singular event, enabling it to leave its mark over a number of years.

6.3.7 Summary of dental disease

Individuals from the German study samples had a higher prevalence of all dental disease, with the exception of dental calculus. However, this result might have been influenced by extrinsic factors such as post-mortem loss of calculus deposits. A high frequency of dental disease among German skeletons is commonly observed and has been commented on by Kunter (1974a: 320), who attributed, among other pathological changes, high rates of caries, periodontal disease and "periapical osteitis" to skeletal remains from southern Germany. Unfortunately, he did not detail reasons for these remarkably high prevalence rates.

Although diet was probably very similar between the observed samples, regional variation in the consumption of cariogenic foodstuffs cannot be ruled out. However, with the lack of faunal and floral remains for the study sample, no conclusions can be drawn. Local availability, or rather absence of fluoride might have contributed to the generally worse state of oral health observed for German individuals.

6.4 JOINT DISEASE (ARTHROPATHIES)

6.4.1 Extra-vertebral osteoarthritis

Temporo-mandibular joint (TMJ) disease

There was no significant difference between British and German individuals with regard to temporo-mandibular joint disease (Tables 5.4.1 and 5.4.2). From the three

British samples, 5.73 percent (9 of 157 individuals) of individuals and 4.22 percent (10 of 231 individuals) of German skeletons had experienced temporo-mandibular joint disease. This result is interesting in the light that TMJ disease is associated with articular changes due to excessive wear or dental disease, such as ante-mortem tooth loss (AMTL). However, more German individuals had experienced dental disease, including AMTL, which should have had a negative effect on their temporo-mandibular joints, leading to degenerative changes. Females from both pooled samples had more than twice as much TMJ disease as males (Table 5.4.2). However, only in British samples had females experienced more ante-mortem tooth loss compared to males. A prevalence of 9.33 percent (268 of 2,871 observable alveolar sockets) was found for British females, while 4.36 percent (85 of 1,951 alveolar sockets) of British males were affected. Nevertheless, prevalence for German males was slightly higher than for German females (13.11 percent, or 459 of 3,502 alveolar sockets and 12.81 percent, or 514 of 4,013 alveolar sockets). Thus, a higher prevalence of TMJ disease could be explained by a higher prevalence of AMTL in British females, but not in German females. Excessive dental wear might be a contributing factor to TMJ disease and Hodges (1991) has identified dental attrition as being more highly correlated with TMJ disease than ante-mortem tooth loss. However, for the study samples it is not known whether females suffered more dental wear than males, since molar attrition was one of the ageing methods used for adult age estimation. To avoid circular argumentation, the same feature could not be employed for the assessment of temporo-mandibular joint disease. In addition to AMTL and heavy dental attrition, nocturnal tooth grinding (bruxism) has been named as an aetiological factor for TMJ disease (Pérez and Martinez, 1989). The majority of modern patients diagnosed with bruxism are women suffering from stress and anxiety (Pschyrembel, 1982). However, there are no means to identify psychological stresses in human skeletal samples and it remains unknown whether early medieval women experienced more pressure compared to men.

The lack of differences for left and right side joint disease is not surprising and should be seen in connection with the movements allowed at this joint. Elevation and depression, as well as rotatory movements, occur simultaneously in both joints (Williams and Warwick, 1980). Even if one side were favoured during mastication because of painful dental problems, this would not lead to a higher prevalence on one side, since dental disease has no side predilection. Equally, Hodges (1991) reported no side differences in her early medieval population from Raunds Furnells, Northamptonshire. Nevertheless, her frequencies were more then ten-times higher than seen in the study samples; 37.1 percent of left and 38.5 percent of right side joints were affected at Raunds Furnells. In comparison, 3.28 percent of left and 2.94 percent of right TMJs from the British study samples, and 3.03 percent of left and 2.59 percent of right TMJs from the German sites, had evidence of temporo-mandibular joint disease (Table 5.4.4). This striking difference between Hodges's results and the present study is a good example of problems with data comparability, introduced by different diagnostic criteria. Hodges (1991: 369) states that "arthritic joints were defined by the presence of erosive lesions" and this less stringent criterion probably led to the higher prevalence rates found at Raunds Furnells. In general, widespread limitations of data comparison of published frequencies of osteoarthritis between different researchers have been discussed by several authors (Waldron and Rogers, 1991; Bridges, 1993; Lovell, 1994).

Upper limb joints

Joints of the human body rarely perform movements in isolation; for example, the activity of eating requires a person to grasp an implement or the desired food item directly with his or her fingers, flex the arm in the elbow joint while lifting the arm, then the person needs to open and close the mouth, and finally chew, thus involving several different joint complexes. One of the advantages of human bipedal gait is that the upper limb becomes freely available to perform tasks and manipulate objects, and therefore, the joints of the arm would experience more activities and more varied movements than joints of the lower limb, which are usually employed in locomotion. Consequently, if activity-induced 'wear and tear' were the main aetiological factor in the development of osteoarthritis, arm joints should be expected to demonstrate a higher prevalence than joints of the lower limb. In contrast, in a modern medical context the large joints of the legs, i.e. hip and knee joints, are more often affected compared to gleno-humeral and elbow joints (Aufderheide and Rodríguez-Martín, 1998). According to a recent study, 50 percent of all people between the ages of 30 and 40 years suffer from degenerative changes of the knee joint. At the age of 60 this figure rises to 90 percent, while osteoarthritis of the shoulder joint (acromio-clavicular and gleno-humeral joints) is less prevalent and usually occurs secondary to traumas (Zilch and Weber, 1989). However, differences in diagnoses and statistical procedures might not make these observations directly transferable to palaeopathology, but nevertheless, a similar trend of finding osteoarthritis predominantly in lower limb joints might be expected for past populations.

In general, there was a striking conformity of prevalence rates between British and German individuals for most joints; the exception was the acromio-clavicular joint, which was more often affected in German samples but not to a statistically significant extent (Figs. 5.4.1 and 5.4.2, Tables 5.4.4, 5.4.7, 5.4.10, 5.4.13, 5.4.16 and 5.4.19). As the interpretation of degenerative joint disease is riddled by its multi-factorial aetiology, the observed uniformity of OA prevalence at joints of the upper limb could be due to very different reasons. Today, and most likely in the past, age is a factor which plays a crucial role in the development of osteoarthritis and this has to be remembered when comparing joint disease frequencies of archaeological human remains. Natural ageing processes account for the deterioration of the cartilage lining a joint's articular surfaces and subsequent minor irregularities will over time lead to more severe bony changes (Zilch and Weber, 1989). To account for this age-related increase in prevalence, the age distribution of individuals with osteoarthritis was tabulated for individual joints (Tables 5.4.6, 5.4.9, 5.4.12, 5.4.15, 5.4.18 and 5.4.21). Degenerative changes in joints of the upper limb were found to increase with increasing age, while only one young adult female displayed OA, affecting the gleno-humeral joint (NT99-1). However, skeletal ageing methods conducted to estimate adult age are far from accurate, although young adults are more likely to be identified correctly due to the presence of late-fusing epiphyses. Additionally, the number of young adults was lower in all study samples than the number of young-middle and middle-aged adults and this might have introduced a certain bias, thus producing low prevalence rates in the young, because fewer young adult skeletons were observable. However, the number of old adults was equally low and the same bias should have acted on old adult osteoarthritis prevalence. As this was clearly not the case, it can be concluded that advanced age did influence the prevalence of degenerative joint disease in both countries. Larsen (1997: 178) stated that "the documentation of age-at-onset of osteoarthritis should provide an indication of when individuals entered the work force," ignoring that this is a slowly worsening condition, which starts with cartilaginous changes not visible in skeletal human remains. In addition, a mono-factorial origin of osteoarthritis, such as labour, seems to be too simplistic.

The correlation of sex with degenerative joint disease is less conclusive than for age (Kissane, 1990). This holds true for modern and archaeological studies, although in most archaeological settings males are predominantly affected (Bridges, 1992). When comparing prevalence rates for upper limb osteoarthritis for the study samples by sex (Tables 5.4.5, 5.4.8, 5.4.11, 5.4.14, 5.4.17 and 5.4.20), the following pattern was observed: for pooled German samples, at all joints, except for hand joints, males had a higher frequency than females, while women had slightly more degenerative changes of their hands (Plate II,1). For three of the six joints making up the upper limb, British females had less osteoarthritis than British males; these were the sterno-clavicular joint, elbow joint and wrist joints. Prevalence was higher for females at the acromio-clavicular and gleno-humeral joints, while both sexes had a similar rate of degenerative changes of the hands. However, none of these differences were verifiable by chi-squared tests due to the low number of affected individuals. A contributing factor to the higher frequencies of OA in the shoulder joints of British females might be due to injuries at this joint. Secondary arthritis of the acromio-clavicular and gleno-humeral joints is a relatively common finding in modern medical practice, where malaligned fractures of the clavicle and habitual dislocations of the gleno-humeral joint introduce non-physiological stresses on joints (Zilch and Weber, 1989). However, fractures of the clavicles and humeri were uncommon in British females (Table 5.5.1 and p. 193). Only 0.5 percent of clavicles (1 of 202 clavicles) and none of the 179 observable female humeri showed evidence of fractures. In contrast, German males had a higher prevalence of clavicle fractures, with 3.47 percent (6 of 173 clavicles), as well as one additional fracture of the humerus (0.61 percent, or 1 of 165 humeri). The male prevalence of 43.75 percent (14 of 32 German male) for degenerative changes of the acromio-clavicular joint was the highest in both pooled samples. Of the five male individuals, who had six broken clavicles, two also had osteoarthritis of the acromio-clavicular joints, while two had changes of the sterno-clavicular articulation only; one also had osteoarthritis of both joints and one had no degenerative joint disease. Tentatively, fractures seem to predispose to joint degeneration, although this has to remain an assumption, because the sequence of diseases cannot be established and a person might well have suffered from joint degeneration first, only to break a bone later. However, dislocations of the gleno-humeral joint were more commonly seen in British females; 3 of 35 females (8.57 percent) with both gleno-humeral joints present had evidence of unreduced dislocations of the shoulder joint and all dislocated joints showed degenerative changes.

Differences in laterality were only observed for German samples, while British skeletons had left and right joints of the upper limb affected to a similar extent (Table 5.4.37). Upper limb joints from the right side had a higher prevalence in German samples. Differences in side prevalence, especially of the right side, are attributed to handedness, since more people are right-handed (Creel, 1966). Lateral dominance of the left cerebral hemisphere and of the right hand for fine motor tasks is unique to humans. Handedness and cerebral dominance are related, because cerebral hemispheres control the movements of the contralateral body segment. The majority of humans have larger left hemispheres and therefore, the majority of humans are right handed (Steele and Mays, 1995). However, for this reasoning right-handedness and consequently a higher right-side prevalence of osteoarthritis should apply equally to British populations. Apparently, preferential use of the dominant side did not lead to increased degenerative changes in British skeletons. As upper limb bone fractures were more prevalent on the right side of German skeletons (1.91 percent, or 12 of 627 bones), when compared to right sided fractures in British samples (0.84 percent, or 5 of 597 bones), joint degeneration secondary to fractures might have led to this result. Again, this has to be regarded as an assumption, since primary and secondary osteoarthritis is difficult to distinguish in skeletal human remains.

Lower limb joints

As expected from the medical literature degenerative changes predominantly affected the lower limbs in both pooled samples (Table 5.4.37). However, high frequencies were only seen in two joint complexes, the hip and foot joints (Figs. 5.4.1 and 5.4.2, Tables 5.4.22, 5.4.25, 5.4.28 and 5.4.31). Hip joints had the highest prevalence of all joints in British samples (16.38 percent, Plate II,2) and the second highest among German joints affected by osteoarthritis (12.5 percent). Today, the hip joint is the second most commonly affected joint in degenerative disease after the knee joint and women are more often involved than men. Primary arthritis occurs in an idiopathic form and it is highly correlated with age. However, 80 percent of all degenerative changes of the hip joint are of the secondary type and occur after deformation of the joint. Reasons for these deformations are numerous, e.g., congenital hip dysplasia, Perthes' disease, slipped femoral epiphysis, rheumatoid arthritis, tuberculous arthritis or after fractures of the femoral neck with subsequent head necrosis (Zilch and Weber, 1989; Apley and Solomon, 1990). However, evidence for any of these causes may become obliterated by osteophyte formation in advanced stages of the condition and no specific primary disease was identified to have caused the observed changes of the hip joints in the study populations.

Contrary to an expected high prevalence of knee joint osteoarthritis, which affects 90 percent of all modern people at the age of 60 years (Zilch and Weber, 1989), degenerative changes of this joint were uncommon in the study populations. This apparent discrepancy has already been noted by other researchers. Baetsen and co-workers (1997) found significantly less osteoarthritis of the knee joint in their random sample of 250 church burials from Alkmaar, The Netherlands, dating between 1750 and 1830. Their results were compared to frequencies derived from radiographic examination of modern Dutch patients. A similar observation of higher involvement of hip joints in British skeletal human remains was made by Waldron (1995), who found considerably less degenerative disease of the knee than the hip joint in pooled samples of well preserved Romano-British and Anglo-Saxon skeletons. In Waldron's opinion, high frequencies of osteoarthritis of the knee joint are a recent development, linked to several possible factors, such as changes in body weight, diet or physical activity. In light of these studies, the lower prevalence of knee joint osteoarthritis in the study sample is not surprising. However, the theory of weight bearing as a factor contributing to joint degeneration of the lower limbs seems to be challenged by these findings, since joints of the hip, knee and ankle should be equally affected by bipedalism and weight. Nevertheless, the ankle joint showed the lowest prevalence among all joint complexes (British samples: 0.51 percent, or 2 of 389 ankle joints; German samples: 0.0 percent, or none of 463 ankle joints) with only one individual, an old adult female from Castledyke South (CS145), having both joints affected. Contrary to this, joints of the feet had a high frequency of degenerative changes, with 4.63 percent (13 of 281 British feet) and 7.44 percent (25 of 336 German feet), respectively. Therefore, weight alone does not seem to be a predisposing factor and once again, the multi-factorial origin of this disease has to be stressed.

Certainly, age was one of these factors and, as for upper limb joints, prevalence of degenerative changes of the lower limb rose with age (Tables 5.4.24, 5.4.27, 5.4.30, 5.4.33). Only two individuals in the young adult category were affected; one a female (NE123) from Neresheim and the other a male (NE138) from the same site. Differences between female and male prevalence rates in both countries followed the same pattern (Tables 5.4.23, 5.4.26, 5.4.29 and 5.4.32). Osteoarthritis of the hip and foot joints predominantly affected male individuals, while slightly more females had experienced degeneration of their knee joints. No comparison for changes of the ankle joint was possible because only one British female was affected. The number of sexed individuals was large enough to test for statistical differences only for osteoarthritis of the hip joint and German males had significantly more degenerative changes than German females, while this was not confirmed for British samples. In modern populations, women tend to have a higher incidence of degenerative knee joint disease than men, although not all epidemiological studies have confirmed this (Felson, 1988). The same statement has been made for osteoarthritis of the hip. However, in archaeological populations, men seem to be more often affected than women (Maat *et al.*, 1995; Waldron, 1997). Differences in the workload of early medieval women and men from the German populations might have been responsible for this result. However, if this were true, differences at other joint complexes would be expected. Furthermore, no statistical significance was reached for the two sexes and differences in sex predilection were only observed for foot joints, which were significantly more often affected in German men. Only one male with osteoarthritis of the foot (PL111) had experienced a fractured proximal first foot phalanx, which might have led to secondary joint degeneration. Primary osteoarthritis of the foot joints in the male part of populations has been attributed to walking or travelling on foot (Walker and Hollimon, 1989; Larsen, 1997). While some sexual division in workload and daily activity may well have existed, a singular reason, such as excessive walking does ignore the multi-factorial origin of osteoarthritis. In addition, the more rugged and mountainous terrain of the Swabian Alb, where the Neresheim and Nusplingen samples derived, should have introduced greater stresses on people's foot joints. However, individuals from Pleidelsheim, a site situated in a wide river valley lacking hostile rock cliffs, showed a similar prevalence to Neresheim and although one-quarter of individuals from Nusplingen had osteoarthritis of their feet, numbers of observable individuals and joints were comparatively small.

Rib joints

Degenerative changes of the costo-vertebral rib joints represent a further problem for interpretation. Ribs articulate with the vertebrae at their heads and tubercles; the first is linked to a facet on the vertebral body and the second to another facet on the transverse process. Ribs are not involved in bearing the body's weight, but they do move to a certain extent when arms are raised or backs are bent. The upper ribs are much less movable than the lower ribs, and the first rib pair is almost immobile, except during deep breathing (Gray, 1998). However, a large number of individuals in both samples displayed degenerative changes at these joints, and although German skeletons had a higher prevalence (29.07 percent, or 25 of 86 individuals) than British individuals (22.4 percent, or 28 of 125 individuals), this difference was not statistically significant (Table 5.4.34). Prevalence by ribs affected with regard to ribs observable provided a different result: 2.99 percent of left and right ribs (89 of 2,974 ribs) were affected in the British samples, while 2.19 percent (46 of 2,101 ribs) had degenerative changes in the German samples. Obviously, 'true' prevalence is more accurately presented by the latter method, since it takes the actual number of preserved ribs into account. However, due to problems with quantifying prevalence of rib joint disease even these rates have to be regarded as grossly under-representing the actual extent of the condition, because osteoarthritis was scored only on rib joints. Degenerative changes seen on vertebral bodies and transverse processes were not recorded due to a lack of correspondence with rib changes. It is almost never possible to accurately identify the specific rib that articulates with a specific vertebra, especially in fragmentary remains. Thus, it cannot be known whether osteoarthritis seen on a rib and a vertebra represents osteoarthritis in one articulation or in two. Since most people have twelve pairs of ribs and twelve thoracic vertebrae, the margin of error is considerably higher.

As seen in other joints affected by osteoarthritis, prevalence for rib joints was linked to age (Table 5.4.36). Only one young adult of undeterminable sex (NT112) had degenerative changes on several rib joints. However, German individuals had a higher prevalence in the next two age categories, and only for old adults, were similar rates reached. Sex was obviously not a predisposing factor, since no significant differences in prevalence between the sexes were found for both pooled samples.

Other forms of possible joint disease

Additionally, two German individuals, an old adult female from Neresheim (NE81) and a middle-aged male from Pleidelsheim (PL113) showed sacro-iliac fusion; the woman on both sides, the male only on the right side (the left was present but not affected). None of these showed signs of external bony bridging of the bones and therefore it was assumed that intra-articular fusion was responsible. The sacro-iliac articulation is a synovial joint, although it is almost immobile because of a taut joint capsule and numerous strong ligaments (Platzer, 1978). However, these joints can still be subject to pathological changes such as inflammation (sacroiliitis), sometimes leading to permanent fusion, or ankylosis (Waldron and Rogers, 1989). Sacroiliitis and subsequent ankylosis of the sacro-iliac joints can occur in a large number of conditions, which, among others, include ankylosing spondylitis (Marie-Strümpell's disease) and psoriatic spondylitis (Rothschild and Woods, 1992; Khan, 2002). Some gastro-intestinal disorders such as Reiter's syndrome, Crohn's disease, Whipple's disease and ulcerative colitis show sacroiliitis (Ortner, 2003). Diffuse idiopathic skeletal hyperostosis (DISH or Forestier's disease), rheumatoid arthritis and tuberculosis may also result in bony fusion of this joint. In DISH, ankylosis of the sacro-iliac articulations is rare, but when it occurs fusion takes place outside the joint surfaces due to connective tissue ossification, a feature that was not observed in the two German individuals. Therefore, a diagnosis of DISH seems to be unlikely, especially in the absence of ligamentous calcification and ankylosis of the spine (Maat *et al.*, 1995; Rogers and Waldron, 1995). In ankylosing spondylitis (AS), sacro-iliac fusion is one of the hallmarks of this disease. However, it occurs bilaterally and today tends to be much more common in men than women, with ratios ranging from 4:1 to 10:1 (Apley and Solomon, 1990; Riede and Schaefer, 1999). In the present analysis, bilateral changes were found in the female skeleton but lacking additional features of AS such as typical vertebral squaring and fusion ('bamboo spine'), and a diagnosis of AS seems to be doubtful. Like AS, modern cases of Reiter's syndrome occur more often in men, but sacro-iliac fusion is unilateral (Rogers *et al.*, 1987), a feature seen in the male skeleton from Pleidelsheim. However, In archaeological human remains, Reiter's disease has so far been reported rarely and a diagnosis based solely upon the fusion of the right sacro-iliac joint is highly debateable. Since both individuals had evidence of osteoarthritis in other joints, it is feasible that this condition was also responsible for ankylosis in the sacro-iliac joints. However, underlying trauma has to be considered as well. Moreover, people might suffer from more than one joint disease at the same time, although the skeletal evidence for a condition other than osteoarthritis was not present. Erosive lesions around the articular facets of specific joints would have had a greater diagnostic value (Rothschild and Woods, 1992).

Summary of extra-vertebral osteoarthritis

Despite minor variation between study samples, overall frequencies and patterns of osteoarthritis affecting extra-vertebral joints, including costo-vertebral articulations, were uniform between the two countries. This was also true when the data was correlated with age, which has to be expected in an age-progressive condition, such as osteoarthritis. With some exceptions, men were generally more often affected than females. The contrary was seen in the shoulder joints of British females and the knee joints of females from both countries. However, these differences were hardly striking. Only osteoarthritis of the feet was found to be significantly more prevalent in German males than in any other subgroup. Nevertheless, there seems to be no readily available explanation for this observation.

6.4.2 Vertebral osteoarthritis

Degenerative changes seen on the different joints of the spine are the single most often observed pathological condition in skeletons in an archaeological context and, just as for extra-spinal osteoarthritis, it is not surprising that numerous attempts have been made to explain and interpret observed patterns. Changes studied most often included degenerative disk disease and Schmorl's nodes seen on the surfaces of vertebral bodies and to a lesser extent osteoarthritis of the apophyseal facet joints (Jurmain and Kilgore, 1995).

Contrary to extra-spinal osteoarthritis some striking differences between the samples were observed in the present study, although some similarities were also present. Prevalence of vertebral osteoarthritis was found to follow the same pattern in both countries, with a significantly higher involvement of the cervical spine than the thoracic or lumbar vertebrae (Table 5.4.38). However, German individuals had experienced significantly more osteoarthritis of their apophyseal joints than British skeletons and this result was contrary to findings made for extra-spinal joint osteoarthritis, where no such marked differences were detected. To obtain more detailed information, differences between female and male prevalence in the pooled samples were investigated (5.4.39 and Fig. 5.4.3). For British individuals, no significant difference was found between the sexes in any of the three spinal areas. However, German males had significantly more osteoarthritis of the thoracic facet joints than German females. Female prevalence, although higher in German women, did not differ significantly between the two countries, while German males displayed significantly more degenerative changes in their thoracic and lumbar spines compared to British males. Therefore, German males did contribute to the observed differences between the countries, especially through their comparatively high prevalence rates in the thoracic and lumbar regions.

As expected, age was highly correlated with increased frequencies of vertebral osteoarthritis (Table 5.4.40 and Fig.5.4.4 for British samples; Table 5.4.41 and Fig. 5.4.5 for German samples). As the cartilage that lines apophyseal facets is subject to the same ageing processes as articular cartilage of other synovial joints, this finding is not surprising. However, there were slight differences in the location of earliest onset. In British individuals the thoracic spine was affected the earliest, while it was the lumbar spine in German samples, but as only one young adult was affected in each country this difference is hardly striking. The highest increase in prevalence with advancing age was found in cervical vertebrae of individuals from both countries. A more detailed analysis including all observable facet joints (Table 5.4.42 for British sites and Table 5.4.43 for German sites) showed a higher prevalence of osteoarthritis on cervical spines for females and males from Castledyke South and Norton, but not for Apple Down, where lumbar facets were more often involved in both sexes. A similar trend was found among German samples; here, Nusplingen and Pleidelsheim had a high female and male prevalence at the cervical spine and (Plate II, 3 and 4), at Neresheim, lumbar facets displayed more degenerative changes in both sexes. However, when data for individual facets was pooled for both countries, British males and German skeletons of both sexes showed a higher prevalence of cervical facet osteoarthritis. British females had more lumbar facet joints with degenerative changes than cervical or thoracic facets (Table 5.4.44). At least partially responsible for this variation might have been the occurrence of spondylolysis as a predisposing factor for osteoarthritis of the facet joints. The term spondylolysis and its complication, spondylolisthesis, describes a separation of a vertebra's neural arch, on which the apophyseal facet joints are located. This separation is understood to be of traumatic origin, but congenital weakening of the affected area might be a prerequisite for the condition to develop (Roberts and Manchester, 1995). In the living person with spondylolysis, the separated neural arch would still be held in place by ligaments. However, the neural arch might have become less stable and this may lead to degenerative changes on the apophyseal joints, since disruption of normal joint congruence can produce secondary changes due to increased stresses. Most cases of spondylolysis occur on the lower lumbar vertebrae L4, and especially L5, therefore a high prevalence of spondylolysis may induce a higher than normal prevalence of osteoarthritis of lumbar facet joints. Females from British sites displayed more osteoarthritis of the lumbar facet joints than British males or German individuals from both sexes and they were also the subgroup with the highest prevalence of spondylolysis of the lumbar spine (see section 5.5.3). However, females from Castledyke South and Norton, but not from Apple Down, actually had a high prevalence of osteoarthritis of the lumbar facet joints. At Castledyke South, a high percentage of females displayed spondylolysis (18.92 percent, or 7 of 37 females), but this was not the case at Norton, where none of the seven females with their lumbar vertebrae present had evidence of spondylolysis. Furthermore, females from Apple Down had an equally high frequency of neural arch separation (18.75 percent, or 6 of 32 females) than that seen at Castledyke South, but lumbar facet joints from Apple Down females did not have an elevated frequency of osteoarthritis of the lumbar spine. Nevertheless, when individual vertebrae with at least one facet joint present were assessed for vertebral osteoarthritis, British females showed relatively high frequencies at the superior and inferior facet joints of L5 (Fig. 5.4.6). Fifth lumbar vertebrae also showed the highest prevalence of spondylolysis; 11.77 percent (10 of 87 L5s) of all fifth lumbar vertebrae from females were affected. This was not mimicked by German females, who had lower frequencies at the level of L5 for spondylolysis (7.69 percent, or 5 of 65 L5s), as well as for osteoarthritis (Fig. 5.4.7). To conclude, while spondylolysis might have influenced the prevalence of osteoarthritis in some populations (e.g., Castledyke South), it is not a universal predisposing factor, as demonstrated for females from Apple Down.

Additionally, other factors have to be considered for the development of osteoarthritis in past populations. Vertebral osteoarthritis has to be seen as a direct consequence of the human posture and bipedal gait (Bridges, 1994; Knüsel, 2000). Mechanical stresses act differently on different levels of the vertebral column, since vertebrae do not just form a vertical line but develop natural curvatures to provide optimal balance, weight distribution and protection from fracture (Tortora and Grabowski, 1996). For these reasons the thoracic spine and the sacrum curve in a posterior direction (kyphosis), when viewed laterally, while the cervical and lumbar spines show an anterior curvature (lordosis) (Gray, 1998). Where these curvatures change direction, higher stresses are applied to the vertebrae, resulting in a high participation of the fifth cervical (C5) and the fourth lumbar vertebrae (L4) in degenerative changes. The thoracic vertebrae tend to be most affected at T8 (Nathan, 1962). British females had high frequencies at the level between C3/4, T4/5 and L5/sacral facets, approximately following this predicted pattern. In contrast, British males had their highest frequencies at C2/3, C7/T1 and T4/5, with low frequencies for the lumbar spine (Fig.5.4.6). In pooled German samples the observed pattern was similar to the one described for British females (Fig. 5.4.7). German females had the highest frequencies of osteoarthritis on the facet joints of C3/4, T4/5 and L4/5, while German males also had C3/4 and L4/5 involvement, in addition to T6/7. The observed variation within the study samples and deviation from the clinically observed concentration of osteoarthritis at specific vertebrae might result from minor individual differences in the shape of the spinal curvatures. At the cervical spine especially, the curvature is variable and curvature is likely to change during a person's life (Platzer, 1978). Furthermore, pathological conditions leading to changes of the vertebral curvatures, for example various forms of scoliosis (lateral curvature) might lead to excessive stresses giving rise to apophyseal joint degeneration (Zilch and Weber, 1989; Kissane, 1990).

Bridges (1994) thought movement to be more important in the general development of spinal osteoarthritis, since this takes place at the apophyseal joints, while vertebral bodies are responsible for weight bearing. In addition to natural curvature, activity and flexibility might explain why cervical vertebrae were predominantly affected in most of the samples in the present study. In fact, the vertebrae forming the most moveable part of the spine are located in the cervical region, especially between the fifth and seventh vertebrae (Zilch and Weber, 1989). To gain additional information for possible effects of movement on the patterning of vertebral osteoarthritis, affected apophyseal joints were analysed separately by laterality (Figs 5.4.8-5.4.11). In both countries, females and males had more cervical facets affected on the left side, whereas thoracic vertebrae tended to be involved more on the right. The same asymmetrical trend in the distribution of affected sides was observed in a sample of eighteenth and early nineteenth-century individuals from Christ Church, Spitalfields, London (Waldron 1991b). In addition to this trend seen at the cervical and thoracic spine, more lumbar facets showed osteoarthritis on the right side in a prehistoric population of Native American Indians from Alabama (Bridges, 1994). However, Bridges did not mention on which criteria her diagnosis of vertebral osteoarthritis was based. Therefore, her results might not be directly comparable to the present study. In the study samples, the analysis of the lumbar spine was less conclusive, showing a less noticeable asymmetry. This was mimicked by Waldron's observations, which also found a high bilateral involvement of the lumbar facets (Waldron, 1991b); his diagnostic criteria were the same as employed here.

Strong muscular attachments occur on the spinous processes of the thoracic vertebrae, especially on the upper part. The rhomboideus major muscle attaches at the first to fourth thoracic vertebrae, while the ascending part of the trapezius muscle passes almost the entire length of the thoracic spine from T3-T12. The first helps raise the arm, while the latter lowers it again (Gosling *et al.*, 1996). Assuming right-handedness for a large part of the studied populations, a higher prevalence of osteoarthritis especially in the upper thoracic region might be explained by a stronger muscle pull on this side.

6.4.3 Degenerative disk disease (DDD)

With minor variation between individual sites, prevalence rates for degenerative disk disease were similar between the two countries with regard to individuals affected (Table 5.4.45). In British and German individuals, the cervical spine was most frequently involved. However, in the pooled British samples prevalence of the other two spinal regions did not differ significantly. On the contrary, German skeletons showed significantly more degenerative disk disease in the cervical region than in the thoracic or lumbar spine. Nevertheless, when comparing individual spinal regions between the two countries, all differences in observed frequencies were statistically insignificant. Further similarities between the two pooled samples were noticed when sex-specific prevalence rates were analysed (Table 5.4.46 and Fig. 5.4.12). Females had experienced less DDD than their male counterparts, especially in the cervical region, where results differed significantly between females and males (Table 5.4.47 and Fig. 5.4.13 for pooled British samples; Table 5.4.47 and Fig. 5.4.14 for pooled German samples). As previously noticed for vertebral osteoarthritis, the increase in prevalence was highly dependent on age, a result confirmed by clinical observations, where DDD is commonly found in the cervical and lumbar spine of patients over the age of 40 years, "but seldom causes symptoms" (Dandy and Edwards, 1999: 431). To control for differential preservation in individual skeletons, prevalence was also analysed with respect to the number of preserved vertebral endplates within each spinal region. Again, the cervical spine was the most frequently affected part of the vertebral column (Table 5.4.48 for pooled British samples; Table 5.4.50 for pooled German samples). High cervical involvement for severe expressions of degenerative disk disease has been noticed in a study of Bronze Age skeletal human remains from Harappa, India (Lovell, 1994).

However, Lovell's diagnosis of 'vertebral osteophytosis' was based on the presence of marginal osteophytes. Pitting of vertebral body surfaces was scored separately and results should be comparable. Cervical vertebrae of Harappan individuals showed a higher prevalence of surface pitting (18 percent, or 33 of 186 surfaces), than found in the study samples (British samples: 11.11 percent, or 141 of 1,269 surfaces; German samples: 13.7 percent, or 171 of 1,248 surfaces). These differences might be explained by the much higher number of observable vertebral body surfaces in the current analysis. Waldron's observations on spines from Christ Church, Spitalfields, London are somewhat closer to the study samples, if not in time, but at least in geographical area (Waldron, 1991b). Using the same criteria of pitting and roughening of vertebral endplates as diagnostic for 'intervertebral joint disease', his results should be comparable to the current study. However, as overall prevalence rates were not presented, only the distribution of skeletal changes within the vertebral column could be analysed. For both, females and males, frequencies were highest throughout the cervical spine.

Similar to osteoarthritis, degenerative disk disease is most likely caused by a combination of factors leading to vertebral disk degeneration, i.e., age, sex, weight, ancestry and mobility (Rogers *et al.*, 1987; Waldron, 1991b; 1992b; 1994). Overall prevalence rates in both study samples were almost identical. In addition, the same distribution was observed among the sexes, with males showing invariably higher frequencies than females, although cervical spines were predominantly affected in all subgroups. Therefore, it might be concluded that between the study samples few differences occurred in the causes leading to degenerative disk disease. Again, physiological factors might play a crucial role in aetiology, which would result in a similar patterning of degenerative disk disease in human populations. In fact, the cervical, and much less so the lumbar spine, seems to be most often involved and this is mirrored by the areas of highest mobility in the vertebral column. Movement occurs predominantly in the cervical and lumbar spine, whereas the thoracic vertebrae are relatively immobile (Zilch and Weber, 1989).

6.4.4 Schmorl's nodes

Results for the prevalence of Schmorl's nodes were similar between British and German samples (Table 5.4.51). However, significantly more British individuals had Schmorl's nodes located on the thoracic spine than the lumbar region, while lesions occurred to an almost equal extent in the German spinal regions. This is an interesting contrast to the observed patterning of degenerative disk disease, which was more prevalent in the cervical spine, while Schmorl's nodes did not occur on cervical vertebrae. In both countries, females were less often affected than males, but these differences were only significant in German samples (Table 5.4.52 and Fig. 5.4.15). The age dependent increase in frequencies was less prominent when compared to extra-spinal and spinal manifestations of osteoarthritis and degenerative disk disease. In British samples, even young adults showed high prevalence rates and the peak in frequency was reached in the middle-aged adult category (Table 5.4.53 and Fig. 5.4.16). German individuals had a similar prevalence within all adult age categories until they reached old age, where frequency rate increased (Table 5.4.54 and Fig. 5.4.17). Schmorl's nodes are lesions that result from herniation and displacement of intervertebral disk tissue into the adjacent vertebral body. The presence of Schmorl's depressions can be idiopathic, or related to a variety of reasons including congenital factors that produce a weakening of subchondral bone and a disruption of the cartilaginous endplate or they might be caused by strong compression due to trauma (Šlaus, 2002). If congenital factors are largely responsible for the development of Schmorl's nodes, then its early occurrence in the study samples is hardly unexpected. Additionally, degeneration of the intervertebral disk might have led to a slightly higher involvement in older individuals. The importance of a degenerative factor is emphasized by Schmorl and Junghanns (1971: 175):

> "The origin, progression and symptoms of vertebral disk prolapse ... are influenced decisively by everyday demands of life. Fatigue damage, similar to fatigue fractures in the bone, can be produced in disk tissue when the demand surpasses the functional ability."

This functional factor could also explain the differences between female and male prevalence of Schmorl's nodes, with males having higher rates due to harder physical demands. However, only German females had significantly fewer Schmorl's nodes than German males. Nevertheless, when comparing the actual number of vertebral endplates preserved, the difference between female and male frequencies is less impressive, at least in the lumbar spine (Table 5.4.56). Despite numerous studies, both clinical and archaeological, which found consistently higher male prevalence rates, Jurmain (1999: 168) declared that this does not necessarily prove "a functional explanation, in which males 'worked harder'." He claims that systemic influences predisposing young males to develop Schmorl's nodes are just as likely. Ultimately, no single cause might be responsible for the development of Schmorl's nodes.

6.4.5 Activity and joint disease

In general, the interpretation of prevalence rates and patterning of degenerative joint disease in archaeological populations is not straightforward. Usually attributed to intense stresses operating on specific joints due to specific tasks, degenerative joint disease has been used by bioarchaeologists to make assumptions about past activities and behaviour (Larsen, 1997). Researchers have postulated a relationship between strenuous activity and the increase in degenerative joint disease prevalence over time (Stirland and Waldron, 1997). However, other factors should be considered; these include an hereditary predisposition, trauma, increase in body weight, loss of bone mass and age-related loss of fine musculo-skeletal control, as well as bony architectural changes to joints as a consequence of injury, inactivity or old age. With this multitude of factors, it is not surprising that in clinical studies no clear-cut relationship between activity and osteoarthritis was proven. Furthermore, some athletes who undergo a rigorous exercise regime over long periods of time will never develop osteoarthritis (Knüsel, 2000). Despite growing concern about the simplistic equation of specific activities and degenerative joint disease (e.g., Jurmain and Kilgore, 1995; Jurmain, 1999), interpretations that focus on a single causative factor can still be found in a palaeopathological context. For example, Schulz and Zand (2003: 155) citing Schultz's analysis of the royal skeletons from the Neoassyrian period of Nimrud/Iraq in which he claimed that, "although both queens died at a young age, they showed signs of osteoarthritis, which was caused by their inactive and idle life." To elaborate on this example, in a previous analysis of the same individuals, Schultz and Kunter (1998: 126) concluded that the degenerative changes found on one of the female individuals were due to an "untrained locomotor system," whereas the other, because of the presence of Schmorl's nodes, might have suffered from Scheuermann's disease.

However, lifestyle might have a more generalized effect on the development of degenerative joint disease and in this context it would be interesting to know what activities were performed by the populations analysed in the current study. There seem to be indications that stresses occurring early in life might rather lead to joint degeneration than hard physical labour during adult life (Jurmain, 1999). Yet we do not know when early medieval children entered the workforce. In general, without written records and archaeological evidence deriving from settlement excavations, only a very broad picture of daily chores and activities can be drawn. Early medieval Anglo-Saxon and Germanic law texts give little information on occupation or lifestyle, but they do reflect the emphasis on social stratification within these societies (Eckhardt, 1935; 1974). 'Occupations' mentioned in the Germanic law texts include blacksmith, goldsmith, shepherd, pig herd, horse groom, cook, baker, as well as male and female servants, although no specific term for 'farmer' exists. The individuals referred to were associated with high status households, although themselves of lower status as implied by the low fines payable for their killings (Steuer, 1998). It can be assumed that social rank should dictate the type and amount of workload experienced by a person. However, this rank can change as one might move up or down the social ladder (Steuer, 1982). The surviving grave goods found during excavation of the study samples did not belong to the highest ranks of society and the unelaborated graves did confirm this interpretation, although some variation in 'wealth' occurred (Schahl, 1938/51; Down and Welch, 1990; Sherlock and Welch, 1992; Knaut, 1993; Drinkall and Foreman, 1998; Koch, 2001). However, work related to agriculture would have taken up much of an individual's life or as Hamerow (2002: 125) stated: "The daily life and world view of early medieval communities were undoubtedly shaped in fundamental ways by the agricultural cycle, yet it is difficult to treat farming activities *per se*, precisely because there is so little description of everyday activities." Activities associated with land cultivation and animal husbandry were numerous and it is likely that everybody who was physically able to provide some help would have done so. Some form of gender-related work division did most likely exist, but it is not clear how strict this was. For example, Sofaer Derevenski (2000) found similar frequencies of vertebral joint disease in females and males from medieval Wharram Percy, a rural site in North Yorkshire, and concluded that broadly similar lifestyles and activities might be inferred from this finding. A Frankish law regulates compensation for abduction of girls from weaving huts (Eckhardt, 1935). One might deduce that weaving was an activity undertaken by girls. However, this does tell us nothing about the intensity and duration of weaving itself. Since households were mainly self-sufficient, weaving would have been performed when textiles were needed. This was likely to be the same for other activities, such as the construction of buildings and woodworking, as well as pottery and iron tool production (Bücker *et al.*, 1998). Other more routinely performed tasks related to agriculture and the rearing of animals would have changed throughout the year (Rösch, 1998), demanding a wide variety of movements, putting different stresses on different joints.

An ethnological study conducted on a poor peasant population living in central Calabria, southern Italy, might give some insight into agricultural task diversity in a non-mechanized environment (Rasmussen, 1968-1971): during harvest time, members of a family, perhaps helped by neighbours and relatives, are involved in harvesting the crop, which consists mainly of wheat. Men usually cut the grain with sickles, while women bind it into sheaves. The harvester has to bend down, grasps the stalks with his left hand and pulls the sickle towards his body, thus cutting the straw. After the harvest, poor people who do not own land, glean the field for forgotten grain. Then women carry the large loads of grain bundles on their head or, if available, sheaves are put on donkeys to bring them to the threshing floor. Men use pitchforks to pile up the harvest in heaps of one-meter height, cutting off the bindings in the meantime. Threshing is done with a team of oxen, which is driven over the piled up straw and grain, pulling a threshing stone. The oxen are driven over the wheat until the top layer of straw and grain is reduced to small fragments, then the straw is turned with pitchforks and the process is repeated until all the harvest is ground into small pieces. During this process the oxen are free to urinate and defecate into the straw. Winnowing is again done by means of pitchforks that are used to throw grain into the wind to sift out pieces of straw. Then the grain is separated from the chaff with winnowing shovels; usually these two processes are done by men, while women separate foreign objects, such as stones from the grain by using brooms.

These and other tasks included harrowing, sowing and weeding. In addition, fodder for animals had to be collected or, alternatively, animals had to be allowed to graze. Cows had to be milked, eggs collected and water fetched. An endless circle of daily activities would have been unavoidable for early medieval peasants. Judging from the distribution of joint disease, individuals from the study samples had a comparable lifestyle, and therefore the observed similarities in patterning and frequency for most of the discussed joints might have been influenced by this. In the end, however, this might be a superficial analogy, since there are no independent means to affirm that all the individuals in the study samples were exclusively farmers, although this seems to be the likeliest explanation. Until the eighteenth century more than 80 percent of western populations lived in a rural environment, lacking mechanized power, which meant they had to be physically active. (McKeown, 1988).

Ultimately, the question has to be asked whether osteoarthritis is a good measure of human activity. Lately, Waldron (1994: 101) has suggested that the assessment of patterning of "enthesophytes may be more sensitive – since in the absence of some other diseases – these occur at tendon insertions which have been subjected to the trauma subsequent upon continual wear and tear." However, enthesopathies may be secondary to other conditions such as ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis (Shaibani *et al.*, 1993). As testosterone is involved in ligament repair, men tend to have a higher prevalence of enthesopathies than women, thus compromising their assessment in archaeological human remains (Rogers *et al.*, 1997). Alternatively, alterations in bone mineral content, bone density and cross-sectional asymmetry may also be good indicators of activity (Jurmain, 1999; Knüsel, 2000).

6.5 TRAUMA

6.5.1 Postcranial fractures

Long bone fractures

While it is rarely possible to correlate fractures with a specific cause, several variables might be taken into account when assessing traumatic injuries. These factors include age, sex, environment and climate, and most important lifestyle. In modern clinical studies children and the elderly, particularly females, are considered most at risk (Singer *et al.*, 1998). While children have not been included here, as no fractures were evident in subadult bones, it is possible that some of the fractures observed in adults – especially the ones that displayed well-remodelled callus formation – might have occurred during childhood. On the other end of the age spectrum, elderly females did not show elevated long bone fracture frequencies. This might attest to a more active life for these early medieval women preventing osteoporotic bone loss and the typically associated rise in fracture prevalence. However, an increase in vertebral fractures in women of advanced age was noticed (see 6.8.2 Osteoporosis). Today's ratio for female to male bone fractures is 1:3. The ratio found in the early medieval samples was 1:6 and 1:4 for British and German individuals, respectively. The difference between the sexes was found to be significant in the German samples. As only three British females had sustained fractured long bones, no chi-squared test could be performed to assess statistical significance. However, British males were six times more likely to have long bone fractures than British females. Contrary to this finding, studies by other researchers reveal no significant differences in fracture frequencies between males and females. For example, Lovejoy and Heiple (1981) noted that Native American Indian women and men from the Libben site (Ohio), dated to ca. 500-1200 AD, were affected by fractures to an equal extent. In a British late medieval context from York, more men than women had sustained fractured long bones (excluding the clavicle); 40 percent of fractures occurred in females. Despite the higher male involvement, the difference was not statistically significant (Grauer and Roberts, 1996). The same male predominance in fracture frequency was found for five more late medieval cemetery populations (Grauer and Roberts, 1996: Table 8). This pattern was explained by the highly patriarchal structuring of society, allowing women little freedom in choosing a profession outside of household duties or shop assistants (Goldberg, 1986). However, early medieval British and German women from the study samples appeared to be even less at risk from fracturing a long bone than their late medieval counterparts (e.g., Tables 5.5.25 and 5.5.26). This was also reflected in the sex distribution of individuals with multiple long bone fractures – only two women from the German samples had more than one long bone fracture, while six men had suffered multiple trauma. However, with only seven females affected in the pooled German samples, this appears to be a high frequency. This might be related to the location of the fractures; both involved the tibia and fibula from the same side and they might have been broken during a single episode. In a clinical context, combined tibia and fibula fractures are more commonly seen than isolated fractures of either bone (Baumecker, 1938).

Some researches studying long bone fracture patterns have noticed a tendency of older individuals to have a higher prevalence rate due to the accumulation of fractures over time (e.g., Judd and Roberts, 1999). The evidence for an age-related increase in fracture prevalence was less obvious in the study samples (Tables 5.5.29 and 5.5.30, Fig. 5.5.2). However, here only the relative distribution of fractures within individual age categories was analysed. Interestingly, only one of the eight individuals with multiple long bone fractures was a young adult (NU169) and two were young-middle adults (NE5 and PL131). The majority of individuals with more than one long bone fracture were middle-aged (CS93, NE30 and NE80) or old adults (NE102 and PL79). Similarly, Judd (2002) found more males sustaining multiple trauma in clinical and archaeological contexts. In modern studies, younger men were at a higher risk and this might have been the case for the individuals from the study samples, although the age when the fracture was received cannot be established.

Next to age and sex, the environment might have a crucial influence on fracture incidence. Obviously, the rougher the terrain, the more likely one is to experience a fall and break a bone. For example, the adverse environment in which skeletal populations in Nubia lived was thought to be responsible for the high prevalence of long bone fractures (Kilgore *et al.*, 1997). Although in Britain a constantly growing body of settlement data exists, in Germany there is still a considerable lack of early medieval settlements preserved and excavated, and for none of the six cemeteries discussed here, have the associated settlements been found. It is known from other excavations that burial grounds and living quarters were situated close by (e.g., Bücker *et al.*, 1998) and, taking this as a rule, the environmental conditions between cemetery and settlement should have been comparable. All of the English sites were placed on relatively gentle slopes (Down and Welch, 1990; Sherlock and Welch, 1992; Drinkall and Foreman, 1998). In contrast, only one of the German sites (Pleidelsheim) lay in a wide river valley (Koch, 1991), while the two others were located in a rocky area with hills as high as 900m, providing more opportunities for falls and subsequent injuries (Eble, 1955; Knaut, 1993). Equally, the climate, although warm and dry in summer, was more adverse for the people living in early medieval Germany, with prolonged snowfalls in winter, again providing plenty of opportunity for slips and falls, especially in combination with the more rugged topography.

Both early medieval societies practiced small-scale agriculture based on crop cultivation and animal husbandry (Christlein, 1979; Arnold, 1988). Today, agriculture is regarded as a dangerous occupation with a high incidence of injuries, including fractures (Judd and Roberts, 1999). A large number of recorded accidents is due to the handling of animals as well as falls from farm vehicles or barns and lofts. Falling objects such as trees or hay bales account for some of these accidents. Labour is still traditionally separated into male and female workspaces with women tending the house and garden, and only occasionally joining in heavier work reserved for men. Interestingly, a modern accident report reviewing farming-related injuries in Tasmania found that 90 percent of trauma was sustained by men and 58 percent of injuries were due to livestock management and handling (Mather and Lower, 2001). Similarly, early medieval women showed a low prevalence of trauma and this may be related to some labour division in male and female tasks. Women were probably most likely to experience mishaps such as falls during daily activities such as the fetching of food items, wood or water from a source outside the house. Other activities concentrated around the house would have included baking, milking, brewing, fowling, spinning and weaving (Bennett, 1987). Likewise, dwellings could have been responsible for harbouring tripping hazards such as small domestic animals, especially in poorly lit interiors. It is difficult to assess what these early medieval houses looked like and one has to rely on sketchy reconstructions (e.g., Addyman, 1972; Schmaedecke, 1995; Bücker *et al.*, 1998). They were probably single-storied and the only light would have come from a central fireplace. However, wooden candlesticks were found during a cemetery excavation in Oberflacht (southwestern Germany), where organic preservation was exceptionally good and candles made from bee wax would have provided an additional source of light (Paulsen, 1992; Wolf, 1998). Elevated storage facilities can only be assumed, but if in existence, they would have been an additional source for falls, maybe even from a considerable height. Further activities, which were presumably conducted by males, contained an even higher injury risk. These include the construction of houses, and numerous other tasks linked to farm work, which changed in intensity throughout the year, but included the handling of probably not always well-tempered animals not only while butchering them, but also during ploughing. Although plough technology had not yet evolved to the heavy ploughs drawn by teams of six to eight oxen known from the eleventh century on (Langdon, 1994), directing small teams of draught animals could have been hazardous even if early medieval cattle were not as tall as their modern descendents (Kokabi, 1998). Early medieval textual evidence from Ireland implies that at least two, or probably four oxen would have made up a team (Lucas, 1972). Furthermore, animal-drawn carts and wagons could contribute to traumatic injuries – bones can break during falls from a vehicle, and limbs might become caught in or under a wheel. Horse riding bears its own dangers, again in the form of falls from the animal and, although stirrups were known, their use was probably not widespread (Christlein, 1979: Fig. 51). Additionally, kicks by animals might have led to severe injuries and broken bones. A recent study among Texan cowboys and ranchers addressed injury prevalence in association with animal handling (Criddle, 2001). The majority of trauma was related to horses and mainly affected ranchers, while bulls were responsible for almost all injuries sustained by cowboys. Bystanders, including children, also had a relatively high risk of being injured by an animal. Regional differences in animal husbandry practices might have been responsible for some of the variation in fracture frequency. For instance, sheep farming would bear less injury risks than cattle farming, because sheep are smaller and less aggressive.

However, without direct archaeological evidence no assumptions can be made on which farm animals were favoured at individual sites. In general, early medieval British farming might have been more reliant on sheep than cattle, while the contrary was observed for continental Europe (Hamerow, 2002). Referring to the previously mentioned Tasmanian study by Mather and Lower (2001), it was noticed that sheep farmers had a high incidence of injuries – only 17.5 percent of the surveyed agricultural enterprises were sheep farms, but they accounted for 30.5 percent of the reported injuries. However, these injuries consisted mainly of sprains and cuts, while dairy and beef farmers were more likely to sustain sprains, dislocations and fractures. Only the latter would be evident in skeletal human remains, whereas dislocations may become visible in recurrent cases and sprains would not show at all.

Most of the observed fractures in both study samples are compatible with injuries resulting from indirect forces such as a short-distance fall, resulting in oblique fractures. However, a high percentage of fractures, especially in the German samples, could not be assessed by fracture type, although the preponderance of fractures of the distal third of diaphysis indicated accidental trauma. Both distal oblique forearm fractures and isolated midshaft fractures of the ulna or radius are associated with indirect forces during a fall over a short distance, e.g., a trip where the body falls forward and the impact is broken by landing on one's hand. During a slip, the body falls backwards and the person falls on the flexed arms. If balance were regained before the ground was hit, the lower limb might be fractured or sprained, because of the sudden shift in weight (Sacher, 1996). Clavicular fractures (Plate III, 1) occur as a consequence of falls from some height, such as a horse, or rarely from a fall from ground level on the outstretched arm (Baumecker, 1938; Robinson, 1998). The lower limb (Plate III, 2) is equally at risk of fracturing during falls from a great height or when the foot is anchored, while tripping (Baumecker, 1938).

Similarities in fracture patterning between the study samples and one other fracture analysis were present. At Raunds Furnells, Northamptonshire, the clavicle and fibula were the bones with the highest fracture prevalence (Judd and Roberts, 1999: Table 3). Although slightly later in date (tenth to twelfth century AD), Raunds was described as a farming community and many everyday tasks may have been similar to the ones performed by earlier farmers. However, the overall fracture frequency of 3.5 percent (39 of 1115 long bones) at Raunds was noticeably higher than for the two study samples (0.86 percent, or 18 of 2,095 British long bones and 1.82 percent, or 38 of 2,083

German long bones). Assuming that agricultural accidents were responsible for most of the observed fractures, these discrepancies may indicate differences in the intensity of agriculture.

Although no clear patterning of long bone fractures by side was found for the British samples with respect to upper limb fractures, lower limb bones in both countries, as well as upper limbs in German samples showed a preference for the right side (Table 5.5.28). Since approximately 90 percent of all humans are right-handed (Steele and Mays, 1995), their right arm might be more often used and would therefore be more likely to sustain injury. However, no such side preference would be expected in accidental falls, which might explain the more even distribution of fractures seen in the British study samples.

Few unusual long bone fractures occurred in the study samples. Femoral fractures were rare, and today when seen in younger individuals they are associated with injuries involving considerable forces (Zilch and Weber, 1989). Only one young adult woman had experienced a fracture of the femoral neck (NU102), while the other was a young-middle aged male. Two more femur fractures occurred at the diaphysis; one at the proximal third of a young-middle adult male (AP39) and the other at the middle third of a young adult male (NT91). In addition, one fracture of the tibial plateau was observed in a middle-aged male (NU76). The commonest injury is a fracture of the lateral condyle, as seen here, coined a 'bumper fracture', although it is rarely caused by the impact of a car's bumper. This type of fracture occurs most often in the elderly and results from a fall on the extended knee, where the tibial condyle is driven into the lateral femoral condyle, which acts as a hammer and smashes the articular facet of the tibia (Apley and Solomon, 1990).

To conclude, there are many interacting factors influencing the fracture frequencies and patterns discussed here. Despite the observed difference in overall fracture prevalence for long bones affected in the two study samples (British samples: 0.86 percent, or 18 of 2,095 long bones, German samples: 1.82 percent, or 38 of 2,083 long bones), the percentage of individuals suffering from fractures was not significantly different (British samples: 5.9 percent, or 17 of 288 individuals, German samples: 8.38 percent, or 28 of 334 individuals). This was due to the higher number of multiple fractures in the German sites. For both samples, the observed fractures could have been caused by accidental injuries during day-to-day activities centring around chores related to agriculture, and no 'parry fractures' commonly associated with interpersonal violence were found. However, aggression was not entirely absent, as healed and unhealed weapon injuries attest for some of the German and a few of the British individuals (see 6.5.2 Cranial trauma).

Mandible fractures

In a clinical context, the mandible is the most frequently fractured facial bone. Direct forces, such as a fall on the chin or a kick in the face by a horse may lead to a fractured mandible (Baumecker, 1938). However, they can also be caused by intentional violence (Hussain *et al.*, 1994). Fighting, in combination with alcohol consumption, has been considered responsible for mandibular fractures (Dandy and Edwards, 1998). In an archaeological setting, fractures of the lower jaw are rarely reported and the current study is no exception (Alexandersen, 1967; Lukacs and Hemphill, 1990). Two British and one German individual had experienced this kind of fracture and overall prevalence rates were low, with 1.25 percent of British individuals with preserved mandibles (2 of 160 individuals) and 0.4 percent of German individuals affected (1 of 247 individuals). The mandibular fracture of a middle-aged male (CS78) was located inferior and slightly distal to the right second incisor, leaving a flattened area of spiculated new bone formation on the mandibular body. On the inferior margin, a pointed bony spur grew in a horizontal direction. Only the root of the right second premolar remained, and the crown had fractured ante-mortem as the covering of the root with dental calculus on the occlusal aspect attested. The right first molar and the second maxillary molar on the corresponding side were likewise covered in heavy calculus deposits. Probably the mandibular and the tooth crown fracture occurred during the same incident as dental trauma may be associated with jaw fractures (Alvrus, 1997). The heavy deposits of calculus probably developed because the person did not chew on this side of the jaw, probably because it was too painful to do so before healing occurred. Moreover, the right mandibular fossa displayed an area of eburnation and new bone formation, which could have been caused by secondary osteoarthritis due to changes in joint morphology. The left mandibular fossa was only fragmentary and none of the two mandibular condyles had survived to allow assessment.

The second individual, a young-middle aged male from Norton (NT69) had a well-healed fracture of the left mandibular ramus and this part of the mandible, as well as the coronoid process, were reduced in width when compared to the right side. Overall, the mandible was asymmetrical, but no osteoarthritic changes were found in the mandibular fossae. The only individual affected from the German samples was a young-middle aged male from Neresheim (NE10). He displayed new bone formation in the form of a thin lamina on the internal aspect of the left mandibular body, as well a small area of pitted remodelled new bone formation. The latter indicates that the fracture had become infected but subsequently healed. Mandibular fractures have a high likelihood of becoming infected as they are usually associated with an open wound either on the skin or the oral mucosa, which readily opens a pathway for infiltrating pathogens; these fractures might take months to heal (Baumecker, 1938). In this context, it is interesting to note that all three individuals showed healed fractures. Nevertheless, one of them, the individual from Castledyke South, had experienced lasting complications with problems during mastication as well as osteoarthritis of the right temporo-mandibular joint. It is also of interest that all three affected individuals were male, although with the low number of cases this might have been due to chance. The actual fracture experience in these populations is probably not representative, since perimortem injuries to the mandible may have been missed in the analysis due to their comminuted nature. The interpretation of any of the three healed mandibular fractures is difficult; two were located on the body and one was on the ascending part of the ramus and they could have been caused by direct trauma such as a fall forwards, although falls on the chin are rare since impact is usually buffered by the arms. Nevertheless, one could think of several possibilities why the arms were not used at that moment (e.g., the hands were holding an object or were bound on the back when the person fell forward). A kick in the face, either by a large ungulate, or a direct hit by an opponent's fist, connecting with the victim's chin are possible reasons for the observed fractures. Ultimately, it has to remain speculation as to what caused the three mandibular fractures.

Scapula fractures

In modern populations, scapular fractures are extremely rare, where only 1 percent of all fractures occur on this skeletal element (Baumecker, 1938). They can be caused by direct forces due to a fall on the back or in road traffic accidents, although the scapula is usually well protected against injury by muscles. Additionally, epileptic fits can also lead to scapular fractures (Shaw, 1971). The body of the scapula is the preferred location for fracturing and this has been observed in the sole example from the study samples. A middle-aged male from Pleidelsheim (PL116) showed a healed fracture of the left scapular blade. Since these fractures are usually sustained during a severe incident, other associated fractures might occur (Baumecker, 1938; Dandy and Edwards, 1998). This was the case in the male from Pleidelsheim, who had additional fractured one left metacarpal, two left metatarsals and the right clavicle, which had never healed properly but formed a pseudoarthrosis. However, all these fractures might be unrelated and have happened at different times, but they could also have occurred in one single accident. In an archaeological context, fractures of the scapula are rarely reported, presumably because due to its fragility this skeletal part does not survive well. The example from Pleidelsheim attests that scapular fractures occasionally survive in human skeletal remains.

Fractures of spinous processes and articular facets of vertebrae

In the medical literature, the fracture of the spinous process of the last cervical and/or first thoracic vertebra is known as 'clay shoveller's disease' (Schmorl and Junghanns, 1971; Knüsel *et al.*, 1996). This kind of fracture was observed in the first thoracic vertebra of a young-middle aged male skeleton from Castledyke South (CS21). Just like its English equivalent, the German medical term '*Schipperkrankheit*' ('digger's disease') illustrates its most likely aetiology (Baumecker, 1938). Clay shoveller's disease is described as a stress fracture of C7 and/or T1, rarely reported in archaeological skeletal remains, although excluding the present case five examples are known from British contexts (Stroud, 1993; Knüsel *et al.*, 1996). The fracture of the spinous process is likely to be caused by direct muscle pull and it has been associated with activities such as digging heavy soils (Zollinger, 1937; Schmorl and Junghanns, 1971). However, a variety of other activities including falling from a height, impact from a falling object, hay pitching, root pulling, metal-dipping, car accident, weight-lifting and American football have been reported by Knüsel and associates (1996). While the last three are unlikely to occur in a European early medieval context, the others may be possible scenarios to explain the occurrence of clay shoveller's disease in the present context. Its relative scarcity in human skeletal populations might be related to the fact that clay shoveller's disease is more common in untrained manual workers, which would have implications when digging heavy soils is the main aetiological factor. Assuming that most individuals in the past were subject to considerable workloads from an early age, their bodies should have adapted to physical stresses, making stress fractures less prevalent. However, there is also the possibility that the condition is under-reported in archaeological samples due to the lack of preservation or detailed observation of spinous processes. On the other hand, the high prevalence of clay shoveller's disease observed in workers recruited to construct motorways in pre-World War II Germany might provide some insight (Baumecker, 1938). The workforce largely comprised the unemployed, who were probably not used to the strenuous tasks of road construction, thus sustaining stress fractures of their vertebrae.

The only other vertebral fracture, with the exception of vertebral body fractures, was found in an old adult female from Neresheim (NE81), who had fractured both superior articular facets of the fifth lumbar vertebra. There was evidence of healing in both individuals, CS21 and NE81, with remodelling of the fracture site, although the fractured skeletal elements have been lost post-mortem or had become necrotic and were subsequently resorbed. Fractures of the vertebral articular facets are rare in the clinical literature; they are associated with extreme bending or straightening of the vertebral column (Baumecker, 1938).

In both countries, compression fractures of vertebral bodies were more prevalent in younger (16-35 years) males than females (see 5.8.2 Osteoporosis). However, this difference was not statistically significant. Underlying disease, such as osteoporosis might be considered as a causative factor, but this is unlikely to occur in young individuals, although malnutrition might lead to a general loss of bone mass. In this case, not only vertebrae would be affected but it is most likely that the vertebral body fractures seen in younger individuals were caused by trauma, resulting from falls.

Rib fractures

Rib fractures were relatively common in both pooled study samples, at least on an individual level, where more than 8 percent of all individuals with well-preserved ribs had sustained one or more fractured ribs. Baumecker (1938) declared rib fractures as common and they make up 10 percent of all fractures in modern studies. Although the rib cage is very elastic due to its cartilaginous articulation with the vertebrae, direct and indirect forces might prove too great and one or more ribs can fracture. This can be caused directly by blows and falls on stones, for example, or indirectly by compression forces while being crushed by a heavy object. In addition, repeated coughing and vomiting can result in rib fractures (Lovell, 1997a). The elderly are especially at risk, because their ribs tend to be less flexible (Dandy and Edwards, 1998). Usually, uncomplicated rib fractures heal after approximately four weeks (Schlosser, 1971). In cases where ribs fracture into several parts, severe complications may arise. Freely moveable rib fragments can now pierce the lungs, pleura or nearby blood vessels and cause internal injuries and probably death (Lovell, 1997a). Again, perimortem fractures might be difficult to detect in skeletal human remains and the individuals found with healed rib fractures had probably experienced less severe injuries. However, one young-middle aged female from Apple Down (AP120) showed a total of 15 fractured ribs. Six were from the left and five from the right side of her body, while four could not be sided. The involvement of the left eleventh rib and the right 12th rib is unusual, since the lower ribs are less prone to fracturing due their high flexibility (Baumecker, 1938). Eleven ribs were well healed, while one showed woven bone formation at the fracture site. This can be indicative of newly formed callus that has not yet remodelled into lamellar bone or it can be a sign of infection. Three more ribs had formed pseudarthroses. If these fractures had occurred at the same time severe forces must have occurred to produce fracture of such a high number of ribs. Otherwise, if these fractures represent recurrent episodes of trauma, one might think of repeated blows to the body as seen in modern cases of domestic violence (Walker *et al.*, 1997; Wladis *et al.*, 1999). However, the facial and upper limb region is just as likely to be targeted in female-related domestic violence (Shermis, 1983). As other evidence in the form of trauma to the face and arms was absent in this individual, no conclusive interpretation was achieved. However, since all fractures were of a transverse type, and these occur more often in direct blows to the chest or when coughing (Judd, 2002), direct force seems to be likely. One other young-middle aged female from Apple Down (AP44) had suffered two fractured ribs on her left side; again, one involved the eleventh, the other could not be identified, and both had healed without complications. Nevertheless, multiple rib trauma was not restricted to females. One young-middle aged male from Apple Down (AP126) had six fractured ribs. Two were from the right side and four could not be sided, but all were well healed. Surprisingly, one more female, a middle-aged adult from Castledyke South, displayed a fractured eleventh rib (CS15) and two females from Norton, a young adult (NT107) and a young-middle adult (NT98), had a right second and left third rib fractured, respectively. Upper ribs are as unlikely to fracture as lower ribs, leaving the fifth to ninth rib at the highest risk and Lovell (1997a: 159) stated that "fractures of the first to third ribs and/or sternum indicates that the mechanism of injury was a high kinetic force." So why did five women from the British samples show rib fractures in these unusual locations. In contrast, none of the British males or German females had fractures to the upper or lower ribs, but the percentage of affected individuals in these subgroups was low (Tables 5.5.32 and 5.5.34). However, of the six rib fractures observed in five German males, one occurred on the first and two on the second rib (NU12-1 and NU173), thus involving half of all rib fractures found in German males. Both individuals were old adults and their lesions had healed without evidence of complication. Furthermore, they had sustained oblique fractures that are often associated with indirect forces, making a different injury mechanism possible. Moreover, when laterality was compared between the two countries, left and right rib fractures were evenly distributed in the British samples, while more right ribs were involved in the German individuals (Table 5.5.36). Regrettably, the ultimate cause for these findings remains elusive.

Metacarpal and hand phalanx fractures

Twice as many British males than females had fractured a metacarpal, while none of the German females were affected, but German males had a similar prevalence as British males (Tables 5.5.37-5.5.41). However, the actual number of individuals with metacarpal fractures was low and only 0.35 percent (5 of 1,420 metacarpals) of British and 0.2 percent (2 of 990 metacarpals) of German metacarpals displayed fractures (Plate III, 3) . Equally, few fractures of hand phalanges were seen; 0.39 percent of proximal hand phalanges (2 of 519 proximal hand phalanges) from the German samples and 0.15 percent of intermediate hand phalanges (1 of 650 intermediate hand phalanges) were fractured in the British sample. Judd (2001), in comparison, reported that 3.8 percent of metacarpals, 4.49 percent of proximal hand phalanges and 2.35 percent of intermediate hand phalanges had been fractured in her sample of 55 individuals from Northern Dongola, Sudan. One of the reasons that Judd proposed to explain the high number of hand (and foot fractures) observed, was the examination of questionable cases by magnification, which helped to verify a large number of articular fractures. Therefore, differences in analysis might be responsible for the discrepancy between early medieval and third to second millennium BC Sudanese individuals. However, in modern clinical studies the metacarpals and hand phalanges are often involved in fracture episodes (Baumecker, 1938). Most of them are caused by accidents involving industrial machinery, a factor that does not apply to early medieval populations. However, metacarpal fractures might also result from falls onto the outstretched hand or from a blow to the knuckle (Adams, 1979; Dandy and Edwards, 1998).

Patella fractures

Patellar fractures are rare in clinical studies (Baumecker, 1938). Like other fractures, they can be caused by direct and indirect trauma. Avulsion fractures can occur through sudden contraction of the quadriceps muscle or more directly from falls and blows (Lovell, 1997a; Dandy and Edwards, 1998). While they usually heal well if not comminuted, patellar fractures can result in irregular articular facets and subsequent osteoarthritis. In the study samples, two individuals from the site of Pleidelsheim showed a fracture of the patella. One young-middle aged female (PL13) displayed a healed fracture of the lateral articular facet of the right patella; some marginal osteophytes had already formed here, which may, over time, would have developed into more severe bony changes. The left patella of an old adult female (PL98) also had the lateral facet affected and some remodelled pitting of the articular surface remained from a healed infection in this area.

Metatarsal and foot phalanx fractures

Fractures of the metatarsals and foot phalanges only occurred in four individuals from the German sites; one female (NE133) from Neresheim and three males (PL71, PL111 and PL116) from Pleidelsheim were affected (Plate III, 3). One middle-aged male (PL116) exhibited two fractures of the left second and third metatarsal bones, while the female (NE133) had a single fracture of the right second metatarsal. The young-middle aged male from Pleidelsheim (PL71) had fractured his right third metatarsal and this was the only example of a torsion fracture of a foot bone, where the distal part had healed slightly skewed in a medial direction. Additionally, one old adult male (PL111) had fractured his left first proximal foot phalanx. This resulted in a low prevalence, with 0.32 percent for metatarsal and 0.24 percent for proximal foot phalanx fractures for pooled German samples (4 of 1,257 metatarsal bones and 1 of 414 proximal foot phalanges). Injury mechanisms leading to metatarsal fractures comprise of crush injuries, where one or more metatarsals are involved, and complications are often encountered due to skin damage (Apley and Solomon, 1990). These wounds are more likely to become infected and cause difficulties in fracture healing. However, none of the observed fractures showed evidence of infection and all were well healed, although one male (PL71) had a slightly malaligned third metatarsal. Young adults might suffer from stress fractures; today, these are commonly seen in army recruits, marathon runners and nurses (Apley and Solomon, 1990). The main activity of the first group has also given this fracture the name 'march fracture'. It most often affects the second metatarsal, especially in individuals in which this skeletal element is longer than the first metatarsal. In addition, elderly females suffering from osteoporosis might show metatarsal fractures. However, only one of the three individuals affected was female and she was estimated to be young-middle aged, making an osteoporosis-related fracture unlikely. With the exception of the male from Pleidelsheim (PL71) who had a singular torsion fracture, which might have resulted from a twist of the forefoot, all other fractures could have been stress fractures.

6.5.2 Cranial trauma

There was an obvious disparity between British and German samples with regard to cranial trauma and German individuals exhibited a higher prevalence of cranial injuries. In total, more than 7.0 percent (7.32 percent, or 18 of 246 individuals) of German individuals with their skulls preserved were affected, as opposed to less than 2.0 percent (1.96 percent, or 3 of 153 individuals) of the British samples. There are certain problems when evaluating whether this lack of cranial injuries was matched by other skeletal samples from Britain or, phrased differently, were German individuals in general more prone to sustain cranial trauma? Roberts and Cox (2003: Table 4.2) found a crude prevalence of 2.6 percent in their study of weapon injuries among early medieval British samples (36 of 1,864 individuals from 10 sites). However, this frequency was likely to be higher, since probably not all individuals had their skulls preserved. Furthermore, their study spanned a much wider chronological timeframe including the entire early medieval period to the eleventh century AD. In contrast, the current analysis was restricted to the mid-fifth to approximately early eighth century AD.

All of the four cranial lesions found in the British study samples were healed; three were attributed to blunt trauma, while one was thought to have been caused by an edged weapon. Injuries inflicted by blunt force do not necessarily have to be related to interpersonal violence, as injuries to the skull can happen during accidents. Falls from some height, falling objects or kicks by animals may all be directed to the skull and would leave their marks. As all three injuries found among the British samples were healed, observations of typical fracture patterns that might allow a more detailed analysis were not possible. The lesions were either oval or circular in shape, did not exceed 2 cm in diameter and were shallow. None had penetrated to the internal table of the cranium, making low velocity blunt trauma with a small object the likeliest cause (Walker, 1989; Lovell, 1997a). However, whether these injuries were accident-related or of a more sinister nature has to remain unresolved. One of the British individuals (NT55-1) with a blunt force injury also had an irregular lytic lesion situated in the proximity of the depressed area. As trepanations, caused by intentional removal of a piece of bone, tend to be more regularly shaped, this lesion was attributed to sharp force injury caused by an object with an edged blade. Accidental injury with a weapon appears to be unlikely, although injuries through carelessness while carrying a spear have been mentioned in Anglo-Saxon law (Eckhardt, 1974). However, the pointed tip of a spear or javelin would be more likely to leave a puncture wound and it can be assumed that the male from Norton was probably the victim of intentional wounding. Nevertheless, in all four cases of cranial injuries the individuals survived long enough to allow complete healing, and remodelled pitting was found in only two instances, indicating that some wound infection took place but had healed subsequently. Although long-term survival was thus proved, severe side-effects of the injuries might still have occurred. These comprise of chronic headaches, epilepsy, sight impairment and loss of memory, as well as psychological problems (Wenham, 1989).

Cranial trauma among the German samples was not only more prevalent but also more varied than for British individuals. With regard to individuals affected, injuries were more likely to be caused by blunt force injuries (44.44 percent, or 8 of 23 lesions; Plate IV, 1), while healed and unhealed injuries inflicted by sharp force were found to the same extent (27.78 percent, or 5 of 23 lesions; Plate IV, 2-4). However, when the actual number of injuries sustained was analysed by type, unhealed sharp force trauma exceeded other injury types (Table 5.5.45). This was caused by a higher percentage of unhealed multiple trauma. For example, one male (NE141-1) had four linear cuts on his left parietal bone; all had penetrated through the cranial bone and none revealed evidence of healing. In contrast, all blunt force injuries were healed. However, it is not clear whether this was due to them being less severe, as none of these injuries had penetrated the cranial bone, but left only shallow depressions. Although extensive internal bleeding might still have occurred, complications in the form of infection are less likely in wounds that did not pierce the meningeal tissues directly surrounding the brain (Baumecker, 1938). On the other hand, severe unhealed cranial fractures caused by blunt force might be highly destructive, leaving a fragmented skull. Naturally, these perimortem injuries would be difficult to differentiate from post-mortem damage, a fact which was probably responsible for the relative high amount of healed cranial trauma observed in other human skeletal samples (Jurmain and Bellifemine, 1997). A different line of thought was followed by Weber and Czarnetzki (2000; 2001a; 2001b). They argue that medical treatment of head wounds might have been highly effective, helping the majority of people to survive even severe injury. Germanic law texts, such as the *pactus legis alemannorum*, dated to the early seventh century, mention treatment of head injuries by physicians (Eckhardt, 1935). However, nothing is known about treatment methods nor how successful they were. Remedies for head wounds were also mentioned in the early medieval British 'leech book', a compilation of magical charms and medical knowledge largely derived from the Greek and Roman medical tradition. Here it was recommended to wash a fractured skull with betony and apply a wound dressing of egg yolk and honey (Wakely, 1997). Honey does have certain anti-microbial properties and is effectively used to treat wounds (Crane, 1999). Moreover, honey was the most often called for substance in herbal remedies; it was mentioned 92 times in Bald's leech book (Cameron, 1993). Another recipe was found in the *Lacnunga*, a collection of Anglo-Saxon herbal remedies, prayers and charms, dated to the late tenth and early eleventh century, but thought to be of much older origin (Pettit, 2001). It was advised, "for a broken bone in the head: stinking camomile and *herbe terestre*; boil with honey, and then mix with butter and make an ointment; clap it on the bone and the head will heal" (Pettit, 2001: 131). However, the knowledge of the early medieval physician in treating fractured skulls did not stop here and more doubtful forms of treatment can be found. For example, "if a man's skull is folded up, lay him supine, drive two stakes at the shoulders, then lay a board across his feet, then strike on it with a sledgehammer; it will come right at once" (Cameron, 1993: 39).

While there is little doubt that healed and unhealed cranial trauma caused by sharp force was intentionally inflicted, it is not clear whether blunt force injuries were also caused by aggressive acts or rather due to accidents. In the German samples, the larger number of affected individuals might allow some insight into this problem. The majority of lesions, both blunt and sharp force, were located on the left parietal bone and the frontal bone (Tables 5.5.43 and 5.5.44). Of the eight German individuals who experienced blunt force injuries, five had their left parietal bone affected (62.5 percent), in two cases, the depression was on the frontal bone (25.0 percent), and only one individual had a lesion on the right parietal bone (12.5 percent). Arguing for accidentally induced trauma, this distribution appears to be unusual, as all cranial bones should be equally subject to injury. However, in the light of a clear left side dominance, as one of the two affected frontal bones bore the lesion on the left side, a different scenario might be more likely. Injuries sustained during a face-to-face attack are usually directed to the frontal bone and, even more so, the left side of the skull, since most individuals are right handed (Manchester and Elmhirst, 1980). In contrast, when struck from behind, lesions are more likely to occur on the occipital and right parietal bone (Wahl and König, 1987). The fact that predominantly male individuals were affected (the ratio of women and men with cranial trauma was 1:5), is less helpful in the determination of possible causes of blunt cranial trauma as men are not only likely to be more often involved in violence than women but they also appear to be more accident-prone (Wakely, 1997). Two of the three affected German women had experienced blunt force trauma; one had lesions on the right side of the frontal bone, with the other having them on the left parietal, and these might have been the result of female-directed violence or were purely accidental. Violence against women was prohibited by law and severe fines were charged. For example, in cases where a pregnant woman lost her child due to someone else's actions, either before it was born or within nine days after birth, the aggressor was fined 40 shillings. In comparison, the equivalent amount of money would be requested from someone causing the loss of another person's eye (Eckhardt, 1935). Whether these laws were effectively restricting violence against women, or whether it did not show on their skeletons, remains unsolved. However, there can be little doubt that the young-middle aged women from Nusplingen (NU209) fell victim to a vicious attack. Her right parietal bone showed two linear cuts, one near the top of the head, covering the posterior aspect, the other more on the side of the same bone, just above the right ear. Both cuts displayed smooth and polished margins on the outer table and the diploë. However, the internal table was slightly irregular, indicating that the weapon was probably stuck in the bone and had to be tilted out twice. This would have had a devastating effect, since the forceful removal of the weapon would have allowed extensive bleeding if she was still alive (Du Trevou and van Dellen, 1992). The location of the two cuts makes an attack from behind likely and, as there were no signs of bone remodelling, the assault was obviously successful. Nevertheless, there is no proof that she died from her cranial injuries or from other lesions, which did not leave a trace on her bones. However, these cuts might have been inflicted shortly after her death as a form of mutilation. Likewise, the reason for the attack, whether due to domestic violence or, for example, a raid on the settlement she lived in, remain unsolved.

Warfare could have been one of the possible reasons for the presence of cranial injuries, especially on males from the German samples. Few battles were recorded historically and there is no method to assure whether some or all individuals with cranial trauma were injured during such events. For example, two battles between the Alemanni and the Franks are known through descriptions by Gregory of Tours (538-594 AD) and an anonymous letter of the ninth century (Dirlmeier and Gottlieb, 1978; Koch, 1998). In both encounters, the Alemanni were heavily defeated and came under Frankish rule shortly after 500 AD. However, one of the battles was fought near the modern city of Cologne, some 400 kilometres away from where the three study samples derived, and it might be debatable whether the body of someone killed so far away from home would have been buried in the settlement he lived in. However, this is highly speculative as more, albeit undocumented battles could have been fought closer to the Alamannic settlement area. In addition, as some individuals survived with cranial injuries, they might have sustained them during one of these battles and returned home. Much closer to home would have been injuries sustained during brawls between neighbours, feuds or during attacks on villages by outlaws. However, the first was challenged by some authors, as they argued that people would not carry high status weapons such as swords during daily activities and therefore could not use them in fights (Weber *et al.*, 2001). Nevertheless, the Germanic laws tell a different story: here, murder, incitement to murder, armed fights during carouses, armed robbery and assault are considered. Additionally, monetary compensation for each body part lost due to an attack, and the form of injury, are detailed (Eckhardt, 1935). Interestingly, none of the affected individuals showed evidence of defensive wounds, for example on the arms, which would be expected to be raised to protect the face. However, perimortem long bone fractures might have been missed due to fragmentation and post-mortem damage, but prevalence of healed lower arm fractures was low (see 5.5.1 Postcranial fractures). Although the textual evidence seems to hint at a dangerous and aggressive lifestyle, this might not necessarily have been the case and perhaps these laws should rather be seen as preventive measures. Even so, compared to the British study samples, German individuals had a more perilous life judging from the number of cranial lesions they sustained. The comparatively few cranial injuries found in the British study samples are in stark contrast to the commonly held notion that fighting was the main male occupation. For example, Wilson (1976: 13) summarized that "it has often been emphasized that life in the Anglo-Saxon period was filled with danger, was nasty and was full of trouble ... The threat of violent death was very real."

6.5.3 Spondylolysis and spondylolisthesis

Differences in the frequency of spondylolysis between British and German samples were discernable. This observation was made with regard to crude prevalence (number of individuals affected), as well as for true prevalence (number of vertebrae affected). The frequencies of 12.95 percent (18 of 139 individuals) for the British populations and 13.86 percent (14 of 101 individuals) for the German skeletons are higher than the 2.9 percent (92 of 3,185 individuals) cited for 26 early medieval sites from Britain (Roberts and Cox, 2003: Table 4.28). However, this discrepancy is probably caused by the quality of data available for their study. Since not all published reports gave detailed information on the number of vertebrae preserved, prevalence rates were calculated for the overall number of individual present at each site, regardless of whether they had vertebral elements present or not. Compared to modern clinical textbooks that state a frequency of between 3 and 7 percent for Caucasian populations (Resnick and Niwayama, 1988), rates found in the study samples were elevated. As spondylolysis in present-day patients is mostly asymptomatic, it is often a chance finding during radiographic examination for other diseases. This might explain why the observed prevalence of spondylolysis was higher in the study population.

With regard to the number of vertebrae involved, only marginal differences between the British and German samples were found. Spondylolysis was present in 2.45 percent (20 of 815 vertebrae) of the British and 2.78 percent (14 of 648 vertebrae) of the German vertebrae (Plate V, 1 and 2). These numbers refer only to vertebrae from the twelfth thoracic to the fifth/sixth lumbar vertebrae. This approach was taken due to the different susceptibility of individual vertebrae. Since cervical and most thoracic vertebrae are less likely to experience spondylolysis than lower thoracic and lumbar vertebrae, only vertebral levels with signs of the disease were included. However, this renders the results incomparable to other skeletal studies. Nevertheless, frequencies for specific vertebrae can be evaluated. For example, Stirland (1996) found a male prevalence of 8.5 percent at medieval Norwich, Norfolk and 11.1 percent for the crew of Henry VIII's warship, the *Mary Rose*, at the level of L5 alone. The corresponding figures for males from the study samples were lower; 5.17 percent (3 of 58 L5s) of British and 6.9 percent (4 of 58 L5s) of German males were affected. Since the fifth lumbar vertebra was most often affected in both countries (Fig. 5.5.3), overall prevalence for all affected vertebrae was even lower, with frequencies below 3 percent. Although minor variation occurred for female and male prevalence rates within each country, with regard to vertebrae and individuals affected, these differences were not statistically significant. Accepting an onset of the condition in childhood, as confirmed by clinical studies, this finding indicates similar amounts of physical stress in both sexes and both populations before adulthood. The high prevalence among old adult individuals found in a North American population from Alabama, was associated with age-related bone loss and subsequent fracture at the *pars interarticularis*, especially in females (Bridges, 1989). However, it remains unknown how she estimated the age of onset of the condition and no firm evidence for a late occurrence of spondylolysis can be assumed.

An additional congenital factor might be confirmed by the high percentage of individuals with other congenital conditions of the spine, such as spina bifida occulta and transitional vertebrae at the lumbo-sacral level. Approximately one-quarter of individuals displayed both conditions. However, as the number of affected individuals with both spondylolysis and spinal anomalies was small, this observation should be regarded with caution.

6.5.4 Summary of trauma

Although German women and men had a higher long bone fracture prevalence than their British counterparts, this difference was caused by the number of fractures sustained per bone. On an individual level, although long bone fracture rates were still higher in German individuals, this difference was less marked. In both countries, women had few fractures and no children were found to be affected. However, as the age of occurrence of a fracture cannot be established, this absence of childhood fractures has to be regarded with caution. Furthermore, fractures may have healed without leaving any visible evidence. Fractures of other skeletal elements and joint dislocations were found to be rare, with the exception of rib fractures, which occurred in equal numbers in British and German individuals. The vast majority of these injuries could have been accident-related, occurring during agricultural tasks.

The same cannot be said about the high number of cranial injuries found in the German samples, as many were caused by sharp-edged weapons and men were especially victims of interpersonal violence. More than half of all cranial trauma was healed, although it cannot be proved that medical intervention was responsible for healing, as no trepanations were found in conjunction with cranial fractures. The only case of trepanation was found in a British sample. In contrast, artificial cranial deformation was only present in German individuals.

Lastly, spondylolysis frequencies were similar in both study areas, attesting to similar physical stresses acting particularly on the lumbar spine. This finding also indicates comparable levels of congenital susceptibility to this type of fracture.

6.6 NON-SPECIFIC INFECTIONS

6.6.1 Periostitis, osteomyelitis and osteitis

Since the beginning of palaeopathological research more than 200 years ago, skeletal manifestations of infectious disease have been described in human and non-human specimens (Ortner and Putschar, 1985). In the light of re-emerging infectious diseases such as tuberculosis, and the outbreak of viral infections (e.g., West Nile fever and Ebola haemorrhagic fever) formerly confined to remote areas but now increasingly emerging in densely populated industrialized nations, this indicates that infectious diseases not only played an important part in the distant past but are increasingly relevant to modern society (Barrett *et al.*, 1998). While modern diagnostic criteria are usually able to identify the causative pathogen and provide imminent help for the patient, the palaeopathologist is left to muse about the possible diagnosis of bony lesions observed on the skeleton and their implications (Ortner, 1991).

Despite the high prevalence of reported cases of non-specific infections in the form of periostitis in human skeletal remains from archaeological contexts, a meaningful interpretation of the results is hampered by the multi-factorial aetiology of the observed bone lesions. Clinical diagnostic criteria might not be helpful for establishing the causes of periosteal bone reactions seen on the tibiae of many skeletons, since tibial periostitis is rarely reported in a clinical context (Ortner, 1991). However, Apley and Solomon (1990) list a number of conditions to be considered in radiographic recognition of periosteal new bone formation: Ewing's tumour is a highly malignant tumour leading to onion skin-like layers of new bone formation, osteoid osteoma (a benign tumour), hypertrophic pulmonary osteoarthropathy (usually found in patients with bronchial carcinoma), stress fracture, scurvy and infantile cortical hyperostosis (Caffey's disease), a rare disorder affecting children, which leads to widespread deposits of subperiosteal new bone. In an archaeological context, causative factors particularly of new bone formation on the lower legs but also in other skeletal elements are likely to be of a traumatic or infectious origin. One other factor commonly considered in discussions of periostitis is chronic venous insufficiency leading to varicose veins, which are prone to ulcerations. A varicose vein is defined as an enlarged, painful superficial vein, which develops due to the retention of blood causing enlargement. Today, varicose veins and subsequent leg ulcers are predominantly found in women (Adam *et al.*, 2003). Congenitally defective veins cause varicose veins in three-quarters of all patients. However, they are triggered by several other conditions such as obesity, alcoholism, constipation, thrombophlebitis (the inflammation of veins) and multiple pregnancies. Certain professions, where prolonged standing or sitting is required also predispose to varicose veins (Riede and Schaefer, 1999). They occur predominantly in industrialized countries (Siegenthaler, 1980) and, although their existence in antiquity cannot be disproved, many of the causative factors are probably not applicable to the past, leaving infection and trauma as the main aetiological factors. Nevertheless, surgery performed on varicose veins is known from fourth-century AD medical texts of the Byzantine empire attesting to the antiquity of the disease (Lascaratos *et al.*, 2001). Whether varicose veins were a medical problem in an early medieval agricultural society is unknown. However, other interpretations have been sought, for example, Wells (Hawkes and Wells, 1983) contemplated the presence of a no longer existing disease to explain the high frequencies of periostitis of the tibia found in Anglo-Saxon skeletons.

Despite modern observations which identify infants and children as commonly suffering from infectious disease, none of the British subadults displayed any periosteal new bone formation, apart from focal periostitis (sinusitis and rib periostitis), which will be discussed later. This is particularly striking in the light of subadult periosteum anatomy; the periosteum of children is less firmly attach to the bone cortex to allow the bone to grow and infectious reaction might therefore be more severe. Additionally, growing bones have a better blood supply than adult bone tissue, and pathogens can be more easily distributed via the bloodstream (Lewis, 2000). Frequencies of infectious disease observed in non-adults from the German samples are low compared to the adult part of the population. One reason for the apparent scarcity of infectious diseases in subadults could be because they did not survive long enough for the disease to become chronic and consequently no bony changes could develop. This viewpoint was also adopted by Grauer (1993), who had observed a similar pattern of a low prevalence of periosteal reactions in medieval subadults from York. However, if children died from acute infections, a high proportion of subadult individuals would be present in the cemetery population studied here. Demographic data obtained from an industrialized population of the nineteenth and early twentieth century suggest that childhood mortality was extremely high and analogous rates should be applied to archaeological populations, where non-adult mortality could be expected to be at least as high as 45 percent (Donat and Ullrich, 1971). However, this data might not be directly applicable to prehistoric and historic populations (Czarnetzki, 1995). Non-adult presence within the six study populations was considerably lower than the proposed minimum of 45 percent, or a more conservative figure of ca. 30 percent (Weiss, 1973), with frequencies ranging from 11.83 percent to 34.13 percent (see 5.1 Demography). Nevertheless, the scarcity of non-adult skeletal remains is not restricted to the study populations but has been noted in other archaeologically derived cemetery samples (e.g., Jackes, 1992; Ulrich-Bochsler, 1997). Reasons might be sought in external factors such as poor preservation of fragile children's remains, differential burial outside of communal burial grounds, shallower depths of children's graves leading to higher proportions of plough damage and poor excavational recovery due to the small bones being overlooked (Huber, 1967; Gordon and Buikstra, 1981; Guy *et al.*, 1997). However, some of the observed periosteal reactions seen in subadults from the German sites may have been caused by a disease unrelated to infection. Scurvy, a metabolic disorder due to vitamin C deficiency, can lead to extensive subperiosteal bleeding especially at the insertions of the temporalis muscle, the posterior maxilla and the greater wings of the sphenoid (Ortner and Ericksen, 1997). However, only two of the lesions in question, one seen on a child from Nusplingen (NU202), the other on a juvenile from Pleidelsheim (PL54) did not show typical bilateral changes commonly seen in scurvy (Ortner *et al.*, 1999).

Pitting of the oral aspect of the palate bones occurred in five individuals from the German sites: one child, aged 2-4 years (NE132-1), one female (NU31), two males (NE80 and NU214) and one adult of undeterminable sex (NU35-2). While some degree of pitting on the palate is considered normal, extensive pitting can be seen in inflammations of the oral tissues (stomatitis), but it can also be part of the bone changes observed in leprosy, scurvy or treponemal disease (Ortner and Putschar, 1985; Ortner and Ericksen, 1997). However, none of the other lesions typical of leprosy, such as destruction of the nasal aperture (Anderson, J. G. and Manchester, 1992) were observed in these five skeletons. Females from the pooled German samples not only had significantly higher frequencies of periosteal reaction of their tibiae than females from the combined British samples, they also had a wider variety of skeletal elements showing evidence of new bone formation. Although most of these lesions are non-specific in origin, some might have been part of a systemic condition. A middle-aged female (NE75) not only had slight pitting on both her tibiae, she also displayed an anterior nasal spine reduced in size to a small rounded protuberance and the beginning of remodelling of the inferior margin of the nasal aperture. Additionally, both mesial maxillary incisors and the left lateral incisor were lost during life. The described changes might be indicative of bone involvement seen in lepromatous leprosy (Aufderheide and Rodríguez-Martín, 1998), but they could also be due to venereal syphilis and yaws, which can lead to a similar destruction of the nasal bones (Ortner and Putschar, 1985). Furthermore, soft tissue infection with *Mycobacterium tuberculosis* (*Lupus vulgaris*) occurs in the facial region and can lead to a complete destruction of the nose (Riede and Schaefer, 1999). Other infectious diseases such as gangrenous stomatitis (progressive necrosis of the gums and face), leishmaniasis (infection by leishmania protozoa), actinomycosis and mucormycosis (infections caused by the bacterium *actynomyces israelii* and fungi of the species *mucor*) and Wegener's granulomatosis (an infection of soft tissues, small arteries and veins of probable immunological origin) should also be considered (Pschyrembel, 1982; Kissane, 1990). However, as Manchester (1994: 80) noted, none of these diseases apart from tuberculosis, lepromatous leprosy, venereal syphilis and yaws "have been diagnosed with rhinomaxillary changes in palaeopathology."

A localized cranial lesion was observed on the right temporal bone of a young-middle adult female from Apple Down (AP120) and on the left parietal of an old adult male from Nusplingen (NU173). Both lesions showed evidence of healing and they might have been caused by overlying soft tissue lesions such as a sebaceous cyst, comparable to the circular depressions described on the skulls of twelve late medieval skeletons from the cemetery of St Andrew, Fishergate in York (Stroud, 1993). Furthermore, soft tissue inflammation might have been a causative factor; this was noted as a possible diagnosis for a triangular-shaped lesion on the right parietal of an adult individual from the early medieval cemetery of West Heslerton, North Yorkshire (Cox, 1999).

A similar circular depressed area on the right temporal bone of a young-middle aged female from Nusplingen (NU146) was mirrored by a circular perforation on the left temporal bone. Small remodelled pits around the lytic lesion and on the walls of the depression indicate healing. Again, a cystic lesion might have caused the observed changes, although the perforation could have been initiated by a cranial fistula draining a chronic infected sinus (Kaufman *et al.*, 1997; Aufderheide and Rodríguez-Martín, 1998). However, a definite diagnosis could not be achieved for any of the discussed individuals and they were subsequently classified as having suffered from non-specific infections.

On the other hand, two male individuals – one from the British samples, the other from the German site of Nusplingen – may have suffered from a specific condition. The young-middle aged male from Apple Down (AP152) displayed reactive new bone formation on numerous skeletal elements. Woven pitted new bone was formed on the right antero-lateral aspects of the ninth and tenth thoracic vertebrae, as well as on the external surface of the mandibular rami, while the internal aspects of the frontal and parietal bones were covered with a thin layer of off-white coloured new bone bearing fine vessel impression. Furthermore, all long bones showed periosteal thickening of the diaphyses, except both humeri, which had woven and pitted new bone formation on the posterior aspect of their distal ends. The left fibula was broken post-mortem and a build-up of three concentric layers of new bone formation was observable (Plate VI, 1). Other bones involved consisted of the ilia, where superior to the acetabulum new bone was found on the posterior aspect. All metacarpals, proximal and intermediate hand phalanges as well as all metatarsals and proximal foot phalanges were thickened by woven pitted new bone formation and both left and right metatarsals IV and V were bowed in a lateral direction. Lastly, all right side ribs were enlarged, while none of the left side were involved (Plate VI, 2). Woven pitted new bone was laid down on several bones of a young adult male from Nusplingen (NU139). Both ulnae, the right radius, the ilia, all lower leg bones and both calcanei were affected. Some of the new bone appeared to be only loosely attached to the underlying cortex. However, the bones of the hands and feet were not affected. The observed skeletal changes are probably caused by a disease called hypertrophic osteoarthropathy (HPO), or Marie-Bamberger Disease. Although described in great detail more than a century ago by the French neurologist P. Marie in 1890 and by the German physician E. v. Bamberger one year earlier (Pschyrembel, 1982), its pathological mechanisms are yet unknown. Clinical signs and symptoms comprise of clubbing of the fingers and toes as well as painful swelling of the limbs and joints. This condition occurs in two forms – as idiopathic pachydermoperiostosis of congenital origin and as secondary hypertrophic osteoarthropathy mostly in association with malignant tumours of the thorax. In a clinical setting, the age of onset is relevant for the distinction between the two types, with the primary form occurring in childhood, while the secondary form is more common in the elderly (Aufderheide and Rodríguez-Martín, 1998). Skeletal manifestations of primary and secondary hypertrophic osteoarthropathy involve symmetrical new bone formation of the long and short tubular bones, with layers that might be separated from the cortex. Usually, the middle-thirds of the diaphyses are affected, but new bone can be laid down on the endocranial surface of the skull (Ortner and Putschar, 1985), a feature noticed in the male skeleton from Apple Down. Similar skeletal changes were observed on two male individuals from Wharram Percy, a late medieval site in Yorkshire, with one of them showing periostitis of the ribs restricted to the left side only (Mays and Taylor, 2002). There seems to be a male predilection for the disease, with only 3-5 percent of all cases being of the congenital type (Aufderheide and Rodríguez-Martín, 1998). Modern clinical data states that 90 percent of all individuals suffering from HPO have intra-thoracic cancers, but, before the effective treatment of respiratory infections with antibiotics, 76 percent of all patients were afflicted with lung or pleural infections (Rothschild and Rothschild, 1998). Perhaps it was no coincidence that one male from a Portuguese sample of individuals infected with tuberculosis was also diagnosed with HPO (Santos and Roberts, 2001). However, it was not clear whether the two described skeletons from Apple Down and Nusplingen had suffered from primary or secondary HPO, because the congenital form does not usually lead to a shortened life span, while the secondary type is associated with severe health problems (Aufderheide and Rodríguez-Martín, 1998).

Despite these few examples where a tentative diagnosis could be reached, the vast majority of lesions discussed here can only be described as non-specific. However, a general trend was noticed with skeletons from the German sites exhibiting more lesions than individuals from the pooled British samples. Within the two countries, males had experienced more changes associated with infectious bone reaction than contemporary females did. One reason for this male predominance in infectious disease susceptibility might be connected to men being less well buffered against harmful pathogens. Women might also benefit from their second X chromosome, making them less prone to some chromosomal disorders (Czarnetzki, 1995; Ortner, 1998). Additionally, immune response of the human body occurs in two forms – inherited and acquired immunity (Kissane, 1990). While the first is present from birth, the second can only develop as a response to exposure to certain pathogens initiating the development of antigens. This was possibly not the same for men and women. It can be assumed that men were mainly involved in agricultural tasks such as crop planting and tilling, bringing male individuals into close contact with infectious agents, especially fungi located in the soil and harvested plants. However, women and children were probably not spared from pathogen contact during harvest and food processing. Infectious diseases transmitted by domesticated animals (zoonoses) would not only affect the male part of the population, as close contact during feeding, milking and winter stabling is likely for both sexes. Brothwell (1991) concluded that an animal vector should be considered as a differential mode of infection in skeletal human remains displaying signs of infection. For example, milk can transmit over 30 distinct diseases. Although many infections would leave no trace on the human skeleton, pathogens causing diarrhoea, such as *E. coli*, might have been prevalent in early medieval populations, since they are passed on to humans by farm animals, and may be responsible for compromising the infected person's immune system (Johnston, 1990; Mayon-White, 1990).

A further mode of acquiring immunity takes place during foetal development where maternal antibodies are passed on via the placenta and after birth through breast milk (Tortora and Grabowski, 1996). However, women experience a better immune response to infectious diseases, which is explained by "selective pressure associated with the hazards of pregnancy and childbirth" (Ortner, 1998: 81). However, enhanced female immune reactivity does not explain the prevalence of infectious bone changes seen in men. Skeletal involvement implies that the infected person had survived long enough to show signs of chronic disease. This concept of 'better health makes worse skeletons' was first introduced by Wood and co-authors (1992) and has fundamental implications for any kind of palaeopathological interpretation. To complicate this matter further, what is the meaning of skeletons displaying no evidence of skeletal changes? Were these healthier than individuals with osseous manifestations of disease or did they die before lesions could develop? However, this 'lesion-free' sub-sample of skeletal populations is usually not studied in palaeopathology. Obviously, human skeletal remains with and without pathological changes indicate that people had died for some reason which, especially when occurring in the younger age categories, was not natural. As individuals with pathological bone changes had apparently suffered from some illness, which they might or might not have overcome at their time of death, the question whether skeletons with osseous lesions are indicative of good or poor health is probably ill asked. However, the manifestations of disease on bone does indicate a healthy immune response, because the changes were able to develop.

The presence of active bone lesions when death occurred might indicate that immune reactivity was finally compromised after initially protecting the individual (Plate VI, 3 and 4). Although German skeletons had more active lesions, differences between the two countries were statistically not significant. However, there is no ultimate proof that the illness was active shortly before death and did contribute to the person's death.

One explanation for the observed male predominance of infectious diseases, as well as the higher frequencies for German samples in general, may not be related to immune reactivity but to them having suffered from more traumatic incidents. Traumatic injury does not always lead to bone fracture but singular or repetitive minor trauma can cause inflammation of the underlying bone tissue, particularly in bones with little soft tissue covering such as the tibia which are prone to damage in accidents.

Fig. 5.6.9 detailed different prevalence rates for females and males from both countries. While the clavicle, arm bones and the femur were rarely affected, frequencies were higher for the tibiae and fibulae, especially in German males. The fibula and to a slightly lesser extent the tibia were the bones most often fractured in the German male sub-sample (Table 5.5.27) and injuries not severe enough to induce fracture could have been responsible for at least some of the observed periosteal reactions. However, the clavicle, which was most often fractured in British males, did not display elevated rates of periosteal reaction.

Obviously, reactive new bone formation on the tibia, and to a lesser extent on the fibula is linked to the male sex. Less marked differences in male and female prevalence for tibial reactive new bone have been observed in studies of medieval human skeletal remains (Stroud, 1993; Brothwell and Browne, 1994). However, Powell (1996: Table 49) reported an 'osteitis' prevalence for females of 1.25 percent (10 of 80 individuals) and 11.65 percent (12 of 103 individuals) for males in a skeletal population from Raunds Furnells, Northamptonshire (850-1100 AD). Nevertheless, there are certain problems in interpreting this information: firstly, the term osteitis is not defined and it can only be assumed that it refers to non-specific infection; secondly, data for individual bones is not separated by sex, but since the tibia and fibula are most often affected in this sample, it seems to be a fair assumption that male predilection extends to the lower leg bones. Nevertheless, a higher male prevalence is not universally observed as some population-based studies have found no differences between the sexes or higher female frequencies (Larsen, 1997). Focusing on recent clinical data, periostitis of the tibiae, sometimes in association with inflammation of the *tibialis posterior* muscle that flexes the toes, as well as stress fractures of the tibia, are all commonly seen in poorly trained athletes running on hard and uneven surfaces. The condition known as shin splints can also occur after a period of inactivity followed by vigorous training (Tortora and Grabowski, 1996). Assuming an active lifestyle for both sexes in the early medieval period but higher activity levels for males, due to agricultural activity, over-use of the legs might have been responsible for at least some of the inflammatory responses seen on the lower leg bones.

Additionally, in both sexes an age-related increase was observed, with the exception of young adults from the German samples (Fig. 5.6.2). Nevertheless, the age at which a person was affected cannot be established in healed lesions. Active new bone was more prevalent in the pooled German samples (Fig. 5.6.3), but differences failed to be of a statistically significant magnitude. Only two individuals from the British samples – one young adult and one old adult – had unhealed new bone formation. This predominance of active tibial lesions in the young and old adult age bands was even more pronounced in the German samples attesting that these specific age categories were most at risk. Ribot and Roberts (1996) in their study of subadults from two medieval sites had observed the highest frequency for periostitis on the tibia for individuals from Chichester, West Sussex, in their oldest age category (18 +/- 3 years), which roughly corresponds to the young adult age band (16-25 years) employed in the present study.

Comparing frequencies with published data from other early medieval British and Germans skeletal samples proved to be difficult, despite the fact that periostitis of the tibia is a commonly observed finding (Hawkes and Wells, 1983). The authors report a 7 to 8 percent prevalence seen on the tibiae of skeletons from Worthy Park, Hampshire, a frequency much lower than observed in the study samples. However, a recent skeletal report (Hollack and Kunter, 2001) on early medieval skeletons from southwestern Germany does not detail numbers for non-specific infection. In this context it is problematic to evaluate whether the discussed prevalence rates for the study samples are unusual within their geographical context. However, non-adult periostitis is relatively well-studied in Britain; at Raunds Furnells, Northamptonshire, and at Wharram Percy, Yorkshire 18.5 percent and 12.7 percent of all individuals with observable tibiae were affected, respectively (Lewis, 2002). This indicates high frequencies for the subadult part of these medieval populations, while none of the subadults from the present study samples had tibial periostitis. As both sites – Raunds Furnells (850-1100 AD) and Wharram Percy (950-1500 AD) – were later in date, the relatively high frequencies might be explainable by an increase in population size and density compared to the early medieval period (fifth to early eighth century AD), where settlements were more widely dispersed and infection would not have spread as easily as in more densely populated areas (Czarnetzki, 1995).

6.6.2 Chronic maxillary sinusitis

Compared to other recent studies, the prevalence of maxillary sinusitis in the pooled early medieval British samples was surprisingly low. However, the combined German samples produced similar frequencies to those reported by previous studies (Merrett and Pfeiffer, 2000; Roberts *et al.*, 1998). Rates ranging from below 30.0 percent to as high as 63.0 percent were found in later medieval samples from England and three pooled samples from the Netherlands spanning the early to later medieval period (Panhuysen *et al.*, 1997: Tables 1 and 3). This is contrasted by prevalence rates of approximately 25.0 percent (British samples) and 35.0 percent (German samples; Plate VII, 1). Although additional endoscopic examination of samples reported by various authors may have led to higher frequencies, when comparing the percentage of sinuses preserved – between 23 percent and 52 percent of all individuals had observable maxillary sinuses, it becomes clear that in the present study a large number of sinuses were actually available for examination (ca. 45 percent) even without using an endoscope. Furthermore, data between different studies is not directly comparable, since contrary to this analysis, individuals with at least one sinus were included (Roberts *et al.*, 1998) and prevalence for the present study samples would have been even lower because on an individual basis more skeletons would have been included. However, there are certain problems with partially present skeletal elements. If in the case of a study of maxillary sinusitis, all individuals with at least one sinus are included in the sample, there is no way of knowing whether the absent sinus showed evidence of the disease or not and the observations made on the presence of only one sinus might not be accurate. For this reason, only individuals with both their maxillary sinuses observable were analysed.

Today, sinusitis is a very common problem and infection of the paranasal sinuses may result from upper respiratory tract infections, invasive dental inflammation and to a lesser extent to allergic reactions (Merrett and Pfeiffer, 2000). However, the palaeopathologist can only speculate on the possible causes in the absence of epidemiological evidence. Even the relatively straightforward evaluation of chronic maxillary sinusitis of odontogenic origin is not without its problems. Although the presence of an oro-antral fistula clearly indicates the likely entrance for bacteria infiltrating into the sinus floor, the influence of other odontogenic inflammatory processes in the absence of these fistulae has to be taken into consideration. When comparing different palaeopathological studies, it becomes obvious that different researchers do not necessarily use the same criteria when defining dental inflammation as a causative factor for odontogenic sinusitis. For example, Boocock and co-workers (1995) list fistulae and advanced dental disease, Lewis and associates (1995) additionally included dental abscesses, and furthermore Panhuysen and colleagues (1997) included periodontitis and ante-mortem tooth loss. These different criteria for dentally induced maxillary sinusitis might explain the wide range of frequencies found in sinusitis ascribed to an odontogenic origin, which may be as low as 7 percent (Lew and Sirianni, 1997) or as high as 43 percent of all observed cases of sinusitis (Panhuysen *et al.*, 1997). To complicate the situation even further, it has to be borne in mind that rhinogenic and odontogenic origins of infection may be pooled, since a person might suffer from both – upper respiratory tract infection and dental inflammation at the same time. Naturally, in skeletal human remains, with the presence of oro-antral fistulae and maxillary sinusitis in the same individual, determining the timing of the two events is not possible, because chronic maxillary sinusitis might have already led to bone changes before a fistula from an abscessed tooth broke through the bony barrier of the sinus floor. Alternatively, in a reversed scenario, the fistula-induced bacteria could have ultimately triggered the inflammatory response of the maxillary sinuses. While the latter is commonly assumed in the palaeopathological literature (Boocock *et al.*, 1995; Lewis *et al.*, 1995), the first should not be disregarded.

Poor air quality in the form of constant exposure to wood smoke, crowded living quarters, lack of hygienė and certain specific infections such as tuberculosis and leprosy are all linked to rhinogenic sinusitis (Roberts *et al.*, 1998). In a modern context, air pollution has been identified to increase the risk of chronic sinusitis (Horiuchi *et al.*, 1981). None of the early medieval individuals studied here showed explicit signs of specific infections, although this does not necessarily mean that these diseases were not present. Certainly living conditions were less crowded than in the later medieval period, especially in a rural context, making the spread of infections from person to person less likely.

However, the exposure to wood smoke has to be considered as wood was the only fuel available for fires. Housing in small, over-crowded and ill-ventilated conditions would have certainly elevated the intake of smoke. House types excavated in an early medieval British context are basically restricted to two forms – the *Grubenhaus* and rectangular timber structures, sometimes called 'halls' (Powlesland, 1997). Similar post-hole buildings, some with several aisles, are found throughout the Continent including southwestern Germany (Bücker *et al.*, 1998). Living space was probably not very crowded, since some of these structures were relatively spacious covering more than 35 square meters, but much larger buildings have been excavated (Addyman, 1972; Fehring, 1991; Stork, 1998). Evidence for wooden floors found at West Heslerton, Yorkshire, demonstrates measures to provide protection from the cold and damp ground (Powlesland, 1997). The purpose of the *Grubenhäuser* has been much discussed; they might have served as multi-purpose structures for storage as well as for spinning and weaving (Bücker, 1998). However, *Grubenhäuser* "did not provide housing" (Powlesland, 1997: 107), as it was previously thought, an assumption which has led some researchers to believe that early medieval people lived in "something that hardly deserves a better title than a hovel" (Leeds, 1936: 21). Wells evoked an even more graphic picture describing the spread of maxillary sinusitis (Hawkes and Wells, 1983: 20):

> "Such a condition could be conveyed to many persons as a result of droplet infection being passed on from one to another as they huddled closely together around their fires in the damp chill of a winter's night. It is likely, too, that the smoke laden atmosphere would have aggravated the condition and hastened its spread. We need no great imagination to picture the coughing and the snorting, hawking, snuffling and spitting consequent on a sinus full of pus. The air must have been putrid with the stench of halitosis."

Nevertheless, early medieval living conditions probably provided adequate shelter from harsh climatic conditions. To what degree smoke was a health hazard cannot be evaluated as no complete roof structures survive and ventilation adequacy cannot be evaluated. However, smoke has the tendency to rise upwards and pollution levels inside houses may not have been as high as assumed (Roberts and Cox, 2003). Unlike Roman houses, which often had tiled roofs interfering with efficient ventilation, early medieval houses were probably thatched allowing smoke to escape through gaps (Dirlmeier and Gottlieb, 1976; Fehring, 1991; Rowland, 1999). It is interesting to note that females from both study samples had higher rates of chronic maxillary sinusitis than males. However, the difference was only of statistical significance for the German sites.

Dentally induced maxillary sinusitis was more prevalent, although not statistically significantly so, in males from the German sites; females and males from the British samples were equally affected by odontogenic sinusitis. Therefore, poor dental health could not have been the factor responsible for more females suffering from sinus infections and prolonged exposure to indoor pollution might have been contributing to these findings. The generally higher frequency for maxillary sinus infection may also be related to German individuals suffering more from respiratory infections. These occur especially in children (Kissane, 1990) and although the majority of lesions observed in the two study samples were healed, the highest prevalence for active maxillary sinusitis was found in non-adults. Climate and seasonality can greatly influence the occurrence of respiratory diseases (Waddy, 1952; Siegenthaler, 1980). There is evidence for a decline in climatic conditions for the period between 400 and 800 AD, at least for Britain (Rackham, 1994; Dark, 2000), but the extent of this deterioration is not known for southwestern Germany. Assuming that modern data reflects ancient climatic differences between Germany and Britain, temperatures were more favourable in the latter, where average annual temperatures are ca. 6 C° warmer, at least compared to values from the Swabian Alb, where two of the three German samples were located (Met Office, no date; Mühr, 2003). Pleidelsheim, which lies in a river valley, does have similar average temperatures to Britain (Mühr, 2003; Howe, 1972) and here the lowest maxillary sinusitis frequencies within the German samples were observed. This was also the only German sample where non-adults did not display any evidence for maxillary sinusitis. However, this could have been due to them dying in the acute stage of the disease. On the contrary, subadults from Neresheim and Nusplingen had the highest prevalence of active lesions, while there was a decline of unhealed bone formation with increasing age. Among the British sites, Norton had the highest prevalence and this site is also the site situated the furthest north of all three British samples, thus having the least favourable weather. There is a correlation between cold climate and an increase in respiratory infections, as in cold weather people tend to crowd together indoors, and in doing so, they increase the likelihood of passing on infections (Howe, 1972). Being confined to an indoor environment would also lead to an increased exposure to pollution in the form of wood smoke, which might worsen an existing respiratory problem, or more generally, lower a person's immune response, making them more prone to infectious disease (Institute for Environmental Health, 1994).

Additionally, age seems to be an important factor which has to be considered as there was a noticeable increase in maxillary sinusitis prevalence in the older age categories, which is probably associated with the accumulative effect of the condition. The observed prevalence rates are very likely to be a gross under-representation of the true frequency of the disease as bone is a living tissue and constant remodelling occurs. It is not measurable to what extent existing new bone might have been lost due to osteoclastic resorption. Furthermore, not all maxillary sinusitis sufferers will have proceeded to a chronic stage – either because they recovered or because they died of this or some unrelated condition.

6.6.3 Rib periostitis

New bone formation on the visceral aspect of ribs can occur in a number of infections affecting the lungs or the pleura surrounding them. Lower respiratory tract infections such as pneumonia were likely to have more severe consequences to the individual in an era where antibiotics were not known. Frequencies found in the combined samples of both British and German samples were similar with 5.0 percent of all individuals suffering from some form of respiratory infection (Tables 5.6.17 and 5.6.18). While none of the German subadults displayed periostitis of the ribs, one of the British non-adults had suffered from respiratory problems resulting in new bone being formed on the internal surface of the ribs. Male individuals, especially in the British samples, were at a higher risk than females from the same country. Taking the number of preserved ribs into account, British individuals in the combined sample still experienced higher frequencies, although the highest prevalence was found at Nusplingen. However, here the number of ribs observable was comparatively low and the percentage of rib periostitis was probably not accurate. Compared to the prevalence of maxillary sinusitis, which can be taken as an indicator of upper respiratory tract infection, infection of the ribs, or lower respiratory tract infection was less prevalent. Furthermore, no correlation between these two conditions was noticed. None of the British individuals with rib periostitis had evidence of maxillary sinusitis, while one of the German skeletons (NE97), a middle-aged male, had experienced an additional inflammation of the right maxillary sinus (the left was not preserved).

Roberts and co-workers (1998) conducted one of the few analyses of rib periostitis and maxillary sinusitis on two historic British skeletal populations – the rural cemetery of Raunds Furnells, Northamptonshire and the urban hospital cemetery of Chichester, West Sussex, with Raunds Furnells belonging to the eight to twelfth century AD and Chichester dating to the twelfth to sixteenth century AD. Frequencies of rib periostitis at rural Raunds Furnells were comparable with the current study sample results, 4.4 percent of all individuals had changes on their ribs, while frequencies for the urban site of Chichester were much higher – here, 20.0 percent had experienced an inflammation of their ribs. It was hypothesized that urban pollution was higher resulting in more individuals suffering from respiratory infections.

6.6.4 Endocranial lesions

As with other non-specific infections, endocranial new bone formation might be caused by a number of different conditions, not all of them necessarily due to infectious disease. The frontal bone was most often involved in endocranial new bone formation (Table 5.6.20; Plate VII, 2 and 3), followed by the occipital (Table 5.6.21), but the encountered frequencies were low in both countries (Table 5.6.22). Non-adults from the German samples had the highest prevalence, while British subadults were not affected. The frequency of 11.1 percent seen in non-adults from the combined German samples are comparable to rates observed at Raunds Furnells, Northamptonshire, where 13.7 percent of non-adults had new bone formation on the endocranium (Lewis, 2002). However, British non-adults from the study samples were not affected. Females and males from the German samples had similar rates of ca. 5.5 percent of skulls involved, while males from Apple Down were slightly more often found to have endocranial new bone formation (ca. 7.0 percent). Other researchers have also identified non-adults as being more frequently involved than adults. At the late medieval cemetery from Jewbury, Yorkshire, Brothwell and Browne (1994) reported that more than half of all individuals with endocranial new bone were between 2 and 14 years of age. While only one middle-aged male was affected, young adult females were at a higher risk (40.0 percent); overall prevalence was estimated to be ca. 6.0 percent. Tuberculous meningitis and conditions causing an increase in intracranial pressure could have caused these changes, although other factors should be considered. Pregnancy osteophytes described by Ortner and Putschar (1985) could have led to the bone deposits observed in the young females. Schultz (1987) found one-quarter (16 of 64 skulls) of all children's skulls from medieval (sixth to ninth century AD) Boğazkale, Turkey, affected with endocranial lesions, which he attributed to meningitis, in some cases brought upon by skull trauma. Middle ear infection (otitis media) and mastoiditis might have been responsible as well, although no cases of these focal infections were found. At

Pergamon, Turkey, of the fourteenth-century non-adult population, 64.3 percent (9 of 14 individuals) had endocranial new bone formation which, according to Schultz (1989), may have been caused by an epidemic of meningitis. In four individuals otitis media was associated with the meningeal reactions.

The apparent tendency for children to have more endocranial new bone formation might be indicative of aetiological factors. Meningeal reactions due to inflammation and trauma have been named as primary reasons. In a modern context more than 15 different infectious forms, classified according to causative pathogen and affected tissue, are recognized (Riede and Schaefer, 1999: Table 19.8). Most of these meningeal reactions are life threatening, even with modern drug therapy, but some forms can have a milder course. Some authors have also discussed the possibility of a change in virulence over time, allowing the infected individual to survive long enough for new bone to be laid down (Roberts, 2000b; Lewis, 2002).

6.6.5 Summary of non-specific infections

Regardless of cause, non-specific infections, other than focal manifestations, were abundant on the lower leg bones of male individuals from British and German samples, while females were affected to a lesser extent. Active new bone formation was most prevalent in young and old adults, indicating ongoing infection at their time of death. However, whether death was connected to the infectious processes has to remain unknown.

Maxillary sinusitis more frequently affecting individuals from the German samples. Adult individuals from Norton had the highest prevalence within the British samples, while individuals from Neresheim were the ones affected the most in the German samples. In both combined samples, subadults had a low prevalence of maxillary sinusitis. Overall frequencies between the two countries were not significantly different, although prevalence was higher for the German samples. Differences in frequencies between females and males within the two countries were only significant for the German sites where females had experienced more maxillary sinusitis. Differences between British females and males, as well as differences between females from both countries and males from British and German samples, were not significant. Younger individuals in both countries suffered less from chronic maxillary sinus inflammation than older adults. Active lesions were few in both combined samples. In the German samples, infection of the maxillary sinuses was caused by dental disease more often than in the British skeletons, but differences were not statistically significant. However, older individuals in both countries had experienced significantly more odontogenically induced maxillary sinus inflammation than their younger counterparts. Regional climatic conditions may have played an important role in the development of maxillary sinusitis and might have been responsible for some of the variation observed within and between the two study samples. Higher frequencies seen in women may have been due to differences in lifestyle between men and women, with females being more exposed to indoor pollution, while men suffered more from odontogenic maxillary sinusitis.

Inflammation on the visceral surface of ribs indicative of respiratory infection yielded similar frequencies in both countries for the number of individuals affected. However, the number of ribs showing new bone formation was higher for the pooled British samples. Endocranial changes, which may be associated with meningitis, were seen more often in non-adults than adult individuals from the German samples, while the lesions found in the British samples were restricted to adult males from one site only. This indicates that subadults from the early medieval German sites were at a higher risk of these conditions; they were also found to have the highest prevalence of unhealed lesions.

6.7 Congenital and developmental anomalies

6.7.1 Congenital anomalies of the spine (other than spina bifida occulta)

Cranial shifting on the cervico-thoracic border in the form of cervical ribs was only present in one individual from the British sample (Table 5.7.1). A female from Apple Down had two small bony extensions of ca. 5 cm length, which conform to a Class II cervical rib (Barnes, 1994: 101). This type is sometimes associated with exerting pressure on the brachial plexus, causing pain in the shoulder or loss of sensation in the hand and fingers.

Complete caudal shifts on the thoraco-lumbar border manifest as lumbar ribs on the first lumbar vertebra. Like cervical ribs they are rarely encountered in archaeological remains, either because the prevalence is low or because of non-observation. Cranial shifting on the thoraco-lumbar level was present in one British female, where several rib facets on the lower thoracic vertebrae were absent. The lumbo-sacral border is the site most frequently affected in both samples. Cranial shifting (sacralisation) was more often observed in the pooled British samples, especially in male individuals (Table 5.7.7).

However, statistically significant differences between the two countries occurred only for caudal shifting at this level (lumbarisation), with British skeletons having higher frequencies. The direction of border shifting was much more uniform in the British samples (Tables 5.7.1-5.7.3), while the German individuals showed more cranial shifts (Tables 5.7.4-5.7.6), which are supposed to be less common (Barnes,1994). However, only ten German skeletons displayed transitional vertebrae and the numbers are probably not representative.

Furthermore, one rarely described case of congenital vertebral defect was found in skeleton NE59, a young-middle aged female from Neresheim. The fifth lumbar body was asymmetrically divided into two parts from dorsal to ventral, resulting in a 'butterfly' shape. In the centre of the body each half displayed a semicircular lytic lesion, which showed remodelled margins. These changes have been identified as a rare congenital defect – notochord regression failure (Scholz, 1996). A similar diagnosis has been made for a mature male from the Augustinian Abbey of St James' in Northampton, who showed comparable changes on his twelfth thoracic vertebra (Anderson, 2003). Usually occurring in males, it only affects the vertebral body, where parts of the notochord fail to regress during normal foetal development (Schmorl and Junghanns, 1968; 1971).

One individual, a middle-aged male from Pleidelsheim (PL72) showed congenitally caused ankylosis of the atlas and the occipital condyle on the right side, where the superior articular facet had fused to the occipital condyle. The diagnosis was made because no evidence of inflammation, degenerative or traumatic changes as the origin of the fusion was observable. This so-called atlas occipitalisation results from a complete, or in the case of the Pleidelsheim skeleton, partial congenital fusion of the atlas with the occipital bone. Classified as a transitional vertebra at the occipito-cervical border, it occurs in 1 percent of today's populations and is considered as a relatively uncommon, inoperable and non-life threatening condition (Black and Scheuer, 1996b). Half of all affected individuals experience some neurological compression caused by the shortening of the neck and additional vertebral fusion at the C2-3 level; mandibular anomalies, cleft palate, cervical ribs and urinary tract anomalies have been observed (Aufderheide and Rodríguez-Martín, 1998). Apart from the atlanto-occipital fusion, the Pleidelsheim male had no other congenital anomalies. According to Barnes (1994) caudal shifting at the occipito-cervical border is more common than cranial shifts, resulting in an occipital vertebra.

6.7.2 Spina bifida occulta (SBO)

Since non-sacral spina bifida occulta is only mentioned occasionally in palaeopathological studies, the discussion will mainly refer to sacral SBO. Furthermore, comparisons with results from other researchers are hampered by the lack of definitions given for a diagnosis of SBO as well as the lack of individual bone counts. A mean prevalence of 30 percent was reported for the Guanche population of the island of Tenerife (Canary Islands) and almost half of all skeletons were affected with SBO in the more isolated parts of the island. This high prevalence was thought to be related to biocultural isolation and inbreeding (Aufderheide and Rodríguez-Martín, 1998). Macpherson (1995) described SBO frequencies of 1-10 percent for modern populations, presumably from Britain, but it was not explicably indicated from which country these numbers derived. Roberts and Cox (2003: Table 4.8) reported frequencies for the early medieval period of Britain ranging between 0.5 and 22.7 percent for 20 sites. They found a crude prevalence of 2.7 percent. However, true prevalence was considerably higher, with 8.7 percent (15 of 173 sacra from 3 sites). Clearly the observed frequencies for the study samples of ca. 7.0 percent were similar to this observed rate. Tentatively, it can be concluded that none of the six studied populations had experienced raised levels of extrinsic disturbances during foetal growth, nor were there any noticeable genetic factors acting on these individuals. The exception might have been Castledyke South, where the highest prevalence, for both sacral and extra-sacral SBO, was observed. However, since the causative factors for this congenital anomaly are multiple, a specific reason for this elevated frequency cannot be determined.

6.7.3 Summary of congenital and developmental anomalies

For the discussed cases of spinal anomalies intrinsic and extrinsic factors have been cited as causative. The intrinsic factors are of genetic origin, while extrinsic influences are more varied, with insults to the foetus including toxins, bacterial, viral and parasitic infections *in utero* and maternal nutrient imbalance. Ultimately, extrinsic factors can only produce defects in individuals with "a susceptible genetic background" (Barnes, 1994: 320). Judging from the observed frequencies, the early medieval population from the three British sites analysed here, were more affected by spinal malformations, especially by caudal shifting at the lumbo-sacral border (lumbarisation).

In modern societies, one of the many risk factors identified to promote the development of congenital anomalies lies in parental alcohol consumption (Kissane, 1990). The fourth-century BC philosopher Plato has been described as the earliest source to warn women and men of alcohol abuse during conception and he predicted psychological and physiological deformities of the foetus if this was not observed (Bien, 1997). However, although alcohol was widely known and consumed in early medieval Britain and Germany, its role in the observed frequencies of various congenital anomalies can only be assumed. The same applies to a possible maternal nutritional deficiency during pregnancy, leading to congenital anomalies. There were no definite differences in anomaly frequencies between the pooled study samples and this might indicate that similar factors influencing congenital anomalies were present in both countries. Furthermore, variation in frequencies were less obvious in the three German samples; this might have been due to these populations living in closer geographical vicinity to one another, making them susceptible to the same environmental factors. Variation was much more prevalent in the three British samples, a result which might have been influenced by lack of proximity between the individual sites.

6.8 Metabolic disorders

6.8.1 Cribra orbitalia

Most researchers have accepted cribra orbitalia to be an expression of anaemia in non-adult individuals, since bone marrow physiology does not allow for anaemic skeletal changes in adults (Stuart-Macadam, 1985). In this context, the high prevalence of cribra orbitalia in subadults from both pooled samples is not a surprise (Table 5.8.3). However, non-adults from the German sites experienced a significantly higher prevalence of the condition compared to British subadults. They were also the only sub-sample displaying active lesions at their time of death (Plate VII, 4). Likewise, females and males from the German sites had more cribra orbitalia, leading to a statistically significant difference in prevalence between the two countries (Fig. 5.8.1). Within each country, females and males had similar frequencies, suggesting that in childhood girls and boys had a similar cribra orbitalia experience. However, the decrease in cribra orbitalia with advancing age (Table 5.8.4 and Fig. 5.8.2) indicates that lesions become remodelled in time, although this does not explain the increase of rates seen in the two oldest age bands of the British samples and in the oldest age category of the German samples. Nevertheless, this might demonstrate the lack of correlation between anaemia and a higher risk of dying.

As there are several factors, which can potentially lead to the expression of anaemia on the skeleton, an interpretation of the results might be problematic. Deficiencies in iron, vitamin B_{12} and folic acid – either caused by nutritional lack, mal-absorption or pathological blood loss – are all possible promoters of anaemia. On the contrary, the body's own defence mechanism of withholding iron in times of chronic infection or neoplastic disease, creating an artificial iron deficiency anaemia, can also lead to anaemia.

Hengen (1971) in his survey and discussion of cribra orbitalia concentrated his research on the southwestern part of Germany (Baden-Württemberg) using four samples from different time periods. The first is contemporary with the study samples and one of the sites analysed here – Nusplingen – was also included in Hengen's work. The second period spans the twelfth century to the year 1850, the third, the years between 1852 and 1889, while the fourth, and last, the years between 1890 and 1922. His results for Nusplingen were very similar to the frequencies observed in the present study (Hengen, 1971: Table 2); Hengen found 35.6 percent of cribra orbitalia (42 of 118 skulls), when excluding his least severe intensity-grade (grade 1) and this was indeed the highest frequency he encountered in all his samples. The steady decline of cribra orbitalia from the oldest to the youngest sample was statistically significant (Hengen, 1971: 65). In discussing probable causative factors, vitamin C deficiency was ruled out on the basis of producing different lesions in the orbits, which are distinguishable from cribra orbitalia. Likewise, food shortages, lack of vitamin A, osteoporosis and genetic anaemias were all ruled out, leaving iron-deficiency anaemia as the only remaining factor. Hengen argued further that in his study of skulls from tropical and subtropical areas of the nineteenth and twentieth century, high prevalence rates of cribra orbitalia were observed and iron deficiency anaemia is predominantly caused by parasitic infestation. A variety of gastric parasites can cause severe blood loss and one kind of fish tapeworm (*Diphyllobothrium latum*) is responsible for inducing vitamin B_{12} deficiency (Garrow and James, 1993). However, whether the inhabitants of the early medieval settlements contributing to the study samples had parasitic induced health problems is unknown, as the associated settlements were not found. Hengen (1971) strengthened his argument by the observation that modern children suffer more from helminthic infestations than adults, and a similar pattern was observed in his studies of historic populations. However, in archaeological skeletal remains it is not possible to assess whether adults were truly less affected than subadults because even in the case of severe anaemia adults would not display bony lesions (Stuart-Macadam, 1985). Environmental data from the early medieval settlement of West Stow, Suffolk, showed little evidence for parasitic infestations. Nevertheless, scanty remains of whipworms (*Trichuris*) and roundworms (*Ascarids*) inhabiting the small intestines of humans and animals, as well as one type of protozoal parasite (*Isospora)*, were found attesting that at least a low level of parasitic infection existed. Nonetheless, these results are difficult to evaluate since it was not clear whether the analysed excrements were of human or animal origin (Walker, 1985). A cyst-like structure described as an 'irregular hollow sphere' found with one of the inhumations from Apple Down was identified as a tapeworm cyst (Harman, 1990). More specifically, the cyst was ascribed to the dog tapeworm *Taenia echinoccocus*, which can cause serious problems in humans and usually is transmitted by dogs' faeces (Aufderheide and Rodríguez-Martín, 1998). It was not clear with which individual the find was associated since it was packed with the left hand bones of skeleton AP138A, a middle-aged man, while the catalogue lists the tapeworm cyst as belonging to AP17, an old adult woman. However, neither of these two individuals had evidence of cribra orbitalia, but as the larvae of the dog tapeworm do not feed on their host's blood or induce profound internal bleeding, iron deficiency anaemia would not be induced by this parasite. On the other hand, it is known that dog tapeworms can lead to severe immune responses (Brehm *et al.*, 1999), which would trigger the body's iron withholding defences and consequently lead to iron deficiency. While a certain amount of parasites were probably present in any early medieval population, levels of hygiene were likely to be better compared to urban centres of the Roman and later medieval periods, where the higher concentration of houses and a higher population density made it more difficult to dispose of any human waste or potentially parasite-infested animal excrement. Evidence from West Stow revealed that house floors were kept clean and any waste was disposed of in *Grubenhäuser* or pits (Walker, 1985). From Roman Poundbury Camp, Dorset, a high prevalence of whipworms and roundworms was reported and the human skeletal remains suffered from associated iron deficiency anaemia (Stuart-Macadam, 1991b). However, herbal remedies containing wormwood, white heliotrope or lupine were mentioned in Anglo-Saxon medical texts to be prescribed against intestinal parasites, and, therefore, indirectly attest their existence (van Arsdall, 2002). Furthermore, infections by the sheep liver fluke can be inferred by the symptoms described in Anglo-Saxon medical texts: cirrhosis, vomiting, diarrhoea and abdominal rigidity (Cameron, 1993).

Another parasite – *Plasmodium* – was identified by Hengen (1971) to have the potential to induce iron-deficiency anaemia. Malaria caused by plasmodial infestation leads to the destruction of red blood cells and subsequent anaemia. According to some observations, malaria was present in the northern tributaries of the River Danube in the nineteenth century (De Jong and Steininger, 1956). The valley's slopes on which the cemetery of Nusplingen were situated, was said to be humid and mosquito-infested until the river became regulated in 1895. However, the existence of malaria in this area, reported in the nineteenth century, does not prove the presence of the disease in the early medieval period. Furthermore, Neresheim, which yielded an even higher prevalence rate of cribra orbitalia did probably not experience any exposure to *Plasmodium* as climatic conditions on the northeastern part of the Swabian Alb were even less favourable to the survival of the mosquito.

Repeatedly, the lack of iron in the diets of past people in combination with parasitic infection has been cited as the causative factor for the existence of anaemia found in human skeletal remains (Carlson *et al.*, 1974; Lallo *et al.*, 1977; Fornaciari *et al.*, 1981; Mittler and Van Gerven, 1994; Lovell, 1997b). Reconstruction of early medieval diet has been attempted by several means – either by the direct analysis of faunal remains found in an early medieval context (e.g., West, 1985; Stork, 1998), stable isotope and amino acid analysis of human and animal bones (e.g., Schutkowski and Herrmann, 1996; Schutkowski and Grupe, 1997; Schutkowski, 2000; Privat *et al.*, 2002) or through a combination of textual and archaeological evidence (Hagen, 1992; 1995; Pearson, 1997). However, the lack of faunal remains for analysis due to the relatively low number of excavated settlements of this time period, the costly and destructive nature of stable isotope studies and the expected bias towards focusing on the higher social classes and monastic life in written documents might not present an objective picture. With regard to iron content, the best source of iron (haeme iron) is meat and would have been available from cattle, pigs, sheep/goats, fowl, wild boar, birds and deer (Eckhardt, 1935; Eckhardt, 1974; Arnold, 1988; Hagen, 1992; 1995). While probably all or only a number of these different species were consumed by the individuals who contributed to the study samples, it remains unknown whether the amount of meat was sufficient to provide enough iron to counterbalance any losses. Stable isotope analysis from early medieval Berinsfield, Oxfordshire, attested to frequent consumption of animal protein in the form of meat and/or secondary animal products such as milk, butter and cheese (Privat *et al.*, 2002). Although stable isotope analysis is helpful in determining major food classes, it cannot inform about the prohibiting effects of certain foodstuffs on the body's ability to absorb iron or give us detailed information on the constituent parts of the diet. Dietary products rich in calcium would inhibit haeme and non-haeme iron uptake, while phytates present in grains, seeds, nuts, vegetables and fruits interfere with the absorption of non-haeme iron (Garrow and James, 1993). As bread and other grain-based foodstuffs such as porridge and gruel were likely to be stable items of the early medieval diet (Pearson, 1997), the effects of their high phytate content would have been detrimental. Furthermore, other iron-absorption inhibitors such as phenolic compounds present in all plants would have had the same harmful effect. In contrast, vitamin C present in green leafy vegetables and fruits would have improved iron absorption, but, it is not assessable to what extent vitamin C was consumed, especially in winter. However, there were no ambiguous cases of scurvy in the study samples, a disease caused by the lack of vitamin C. Iron concentrations in vegetables, and subsequently in animals and humans, can vary considerably depending on the iron content of the soil (Heilmeyer, 1964). Neresheim and Nusplingen are situated on the White Jura, a soil which is extremely low in iron leading to reduced iron in vegetation, which would then be passed on to animals feeding on them (Frank, 1951). Furthermore, iron concentration in the water at Nusplingen is close to zero, while other rivers in Baden-Württemberg such as the Neckar are extremely low in iron (Hengen, 1971). As one other site of the study samples – Pleidelsheim – was located on this river, iron deficiency might have been caused by the low concentration of iron in the diet. However, comparable data on iron contents of soil and water for the British samples was not obtainable. Nevertheless, modern surveys showed well-drained soils suitable for agriculture at Apple Down, West Sussex and Castledyke South, Humberside, while Norton, Cleveland, was situated on grassland, which is prone to flooding due to high groundwater, and a risk of manganese deficiency was found in cereals and grass (Jarvis *et al.*, 1984a; 1984b). From this, it might be carefully hypothesized that available iron levels were probably less sufficient in the southwest German populations. Contrary to this assumption, Grupe (1995) found no association between individuals with and without cribra orbitalia and lowered iron content in bone. However, her sample size was very low (20 subadult individuals from the early medieval Bavarian site of Altenerding). On the other hand, amino acid and trace element analyses were conducted on individuals with cribra orbitalia from

Neresheim and Nusplingen (Schutkowski and Grupe, 1997) and for these two sites, a significant correlation between the more severe expressions of cribra orbitalia and a low iron concentration in bone was confirmed. However, more individuals had less severe grades of cribra orbitalia, which was associated with slightly elevated iron levels. This observation was related to the body's defence against infectious disease by withholding iron from the infiltrating pathogen or the presence of other factors inducing deficiencies, which are unrelated to the lack of iron, but are caused by decreased vitamin C levels. The authors argue that since vitamin C increases iron absorption, vitamin C deficiency can also lead to increased iron-deficiency anaemia (Schutkowski and Grupe, 1997). However, since severity of cribra orbitalia is not necessarily correlated with severity of anaemia, this argument is not acceptable. Furthermore, orbital changes caused by anaemia and scurvy can be distinguished from each other, and this aspect was neglected in their study.

Additionally, vitamin B_{12} and folic acid deficiency can lead to anaemia; in a clinical context lack of folic acid has been associated with neural tube defects found in neonates (Medical Research Council, 1991), but recently a deficiency in both vitamins was found to be responsible for these birth defects (Suarez *et al.*, 2003). The lack of evidence for neural tube defects in the study samples has already been discussed (see 6.7.2 Spina bifida occulta). However, their absence might have been caused by other factors. As neural tube defects can be severe enough to make survival of the newborn impossible, these skeletons might not be found in the archaeological record due to differential burial or non-survival of the bones.

Anaemia of chronic disease caused by deliberate iron withdrawal could also have contributed to the observed prevalence rates of anaemia in the six study samples. It would be very tempting to relate the high frequencies of cribra orbitalia found in the three German skeletal populations with the high prevalence of non-specific infection and, likewise, the low prevalence of cribra orbitalia found in the British samples with lower rates of non-specific infections. However, it is not possible to evaluate whether these two conditions – iron-deficiency anaemia and non-specific infections – occurred at the same point in time during an individual's life since cribra orbitalia can only manifest itself during childhood.

6.8.2 Osteoporosis

Bearing in mind the difficulties in diagnosing osteoporosis through the presence of specific bone fractures, the results and following discussion have to remain tentative in nature. Overall, only low frequencies of femoral neck and distal radius fractures were observed (Table 5.8.6) and they only occurred in the German samples. However, females were not at a higher risk of sustaining fractures to these skeletal elements, which are commonly involved in present-day women suffering from osteoporosis (Aufderheide and Rodríguez-Martín, 1998). In fact, only one of the females from the German sites had experienced a Colles' fracture, while three males showed evidence for distal radius fractures. Two of the three males were old adults and the other male and the only affected female were young-middle aged. However, all distal radius fractures were well healed and the age of an individual at the time of fracture cannot usually be assessed. Therefore, the two old adult males might have sustained their broken lower arms much earlier in life and the observed Colles' fractures were not related to any bone-mass reduction in old age. Likewise, one female and one male had each suffered from a fractured femoral neck. None of the them was of advanced age and, again, the data does not support any evidence for osteoporosis-related fractures. However, as fractures of the femoral neck are of a severe nature even with the advantages of modern medicine, any presence of this type of fracture might have become obliterated in the skeletal record due to the difficulties in differentiating between perimortem and post-mortem fractures. Alternatively, femoral neck fractures today predominantly affect women over 75 years of age (Mays, 1996a) and the early medieval people studied here might not have lived to such an advanced age. On the other hand, vertebral body fractures caused by osteoporosis occur at an earlier age than fractures of the femoral neck (Garrow and James, 1993) and this might be reflected in the following results. Prevalence rates for vertebral body fractures (Tables 5.8.7 and 5.8.8) showed clear evidence for an age-related increase for both sexes – however, only differences between younger and older adult females were significant. Nevertheless, this higher prevalence for vertebral body fractures in older individuals might reflect an accumulating effect of fractures in general, since older people tend to have sustained more fractures because they had more opportunity to suffer some accident resulting in a broken bone. However, why did younger and older British and German males show a non-significant difference in their vertebral body prevalence? In both countries, younger males had comparatively more fractures of the vertebral bodies than younger females, although the differences were not of significant magnitude. It might be that this slightly elevated risk seen in younger males is related to them suffering more accidents during everyday activities. In general, males had sustained more long bone fractures than females and these fractures were probably accident-related as demonstrated previously (see 6.5.1 Postcranial fractures). For early medieval women and men agricultural work was part of their daily routine leaving them exposed to accidents and injuries. However, some kind of work division probably existed in the form of men predominantly doing heavier labour, which involved the handling of cattle and carts. Therefore, in their younger years, they were more prone to sustaining fractures than females. However, while male fracture risk rose only slightly with advancing age, females became more susceptible to vertebral body fractures because of bone-mass reduction weakening the trabecular structure. There are certain problems with this interpretation apart from the unreliability of adult age assessment as it is not possible to know whether all observed vertebral body fractures were caused by osteoporosis and were not accident-induced. However, the patterning of female and male vertebral body fracture frequencies and the statistically significant increase of this fracture type in older females may hint to the presence of this disease.

6.8.3 Summary of metabolic disorders

Two different metabolic diseases have been discussed in the study samples. However, only one condition – cribra orbitalia, which is indicative of anaemia, was found to be present unambiguously, but interpretations of possible causative factors are difficult. Nevertheless, individuals from the three German sites had significantly higher rates for this condition and a nutritional induced deficiency of iron might have been responsible for this. On the other hand, iron deficiency induced by iron withdrawal as a response to chronic infection cannot be ruled out. Vitamin C deficiency, or scurvy, was not present in any of the skeletons, although difficulties in diagnosing the disease might have contributed to this. Furthermore, osteoporosis may have been slightly more prevalent in elderly females from the British samples but, again, problems with diagnosis, have hindered a more accurate analysis.

In the concluding chapter, Chapter Seven, a summary of the discussed findings is given. It also outlines the limitations of this analysis and gives recommendations for future research.

CHAPTER SEVEN

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CONCLUSIONS

The comparison of pathological changes seen in the early medieval study populations showed many similarities between the two countries, but also some striking differences in the prevalence of some diseases. A summary of these results is given in Table 7.1. However, as additionally two non-pathological indicators of health and disease – demographic structure and stature – were investigated in the study populations, these conclusions will be summarized first.

7.1 DEMOGRAPHY

Influenced by a number of extrinsic factors, such as skeletal preservation, excavation methods and curation, it was concluded that the demographic structure of the study samples was likely not to represent the once living population. In both countries, non-adult individuals were under-represented, compared to proportions found in historic populations. Assuming that these parameters also apply in the past, a statistically relevant under-representation of children was found. However, clustering of children's burials within cemetery areas was not observed and therefore, non-adults could not have remained undetected in areas which were not excavated. Nor is there any evidence in the early medieval period for children being buried elsewhere, separated from their adult contemporaries (Ulrich-Bochsler, 1997). It may be argued that extrinsic rather than intrinsic factors were responsible for this result. In the six study samples, there were no significant differences in adult and non-adult preservation in terms of completeness as well as bone and tooth condition. This suggests that the under-representation of subadults is not likely to be due to preservational factors. The general state of preservation was assessed by evaluating the condition of bones and teeth, the fragmentation of bones as well as the completeness of each skeleton. The majority of British skeletons were complete or at least partially preserved, while the relatively higher number of incompletely preserved remains from the German sites resulted from disturbances cause by deliberate robbing of graves, probably shortly after burial. Other factors contributing to incompletely preserved skeletons comprised disturbances by subsequent burials. A number of German inhumations were also disturbed by modern building projects or they were truncated because they were partially lying outside the boundaries of archaeological trenches.

In addition, both samples with the highest proportion of non-adults, Apple Down and Norton, were also the only two sites where most of the cemetery boundaries were excavated, thus providing a more complete skeletal sample than the other four sites, which were only partially excavated. In contrast, the site with the lowest proportion of non-adults was Nusplingen; excavated in the 1930s, this sample had not only the longest curation history, but was also excavated without the help of modern archaeological techniques.

The bias towards female skeletons, which was statistically significant in the British samples, cannot be explained by more complete female skeletal remains, which theoretically would lead to more female skeletons being identified. However, a high percentage of adult human remains were not complete enough to be assigned a sex and the distribution of sexed individuals may therefore not be representative.

The same caution has to be applied when comparing age-related mortality within the two samples. Again, the proportionally higher number of infants in the British samples may be related to extrinsic factors, which reflect excavation and curation methods. With the exception of German children aged 2-4 years, childhood mortality was similar in the two pooled samples. Among adults, a comparable distribution within the individual age categories was seen between the two countries. In Britain and Germany, relatively few young and old adults were present, while the majority died in young-middle and middle adult age. Although adult ageing techniques are less reliable than non-adult age estimates, young adults are more readily identified because late-fusing epiphyses can be used. The low percentage of young adult individuals should therefore be closer to the true number than in any other adult age category. In contrast, age assessment of old adults is notoriously difficult and many individuals who were classified as older than 45 years were probably younger, while many young-middle and middle-aged adults were likely to be under-aged.

7.2 Adult Stature and Non-Adult Growth Profiles

The adults from both countries had similar statures. Compared to modern British males and females, there was no difference in height between the three early medieval British samples and their modern counterparts. However, the adults from the three German populations were slightly shorter when compared to modern people occupying the same area. However, when differences in modern and archaeological stature estimation are considered, this difference might not be of importance. Only two adult German individuals were found to have a noticeable shorter stature than their peers, and this might indicate some disturbances during their childhood which led to stunted growth.

Furthermore, since not all individuals had long bone preservation that allowed stature estimates, an unknown number of people might have exhibited stunted growth but remained undetected in the skeletal record. Non-adults from both countries showed similar growth profiles when mean femoral length was plotted against mean dental calcification age. However, differential preservation reduced the number of individuals in each age category and, again, the results might have been influenced by this.

7.3 Dental disease

Almost all the adults from the German samples showed evidence of one or more types of dental disease and frequencies for dental caries, periapical lesions, pulp exposure, ante-mortem tooth loss and periodontal disease were significantly higher in German individuals. Assuming that both populations had a similar diet with equal access to abrasive and cariogenic foodstuffs, differences in the environment, namely the lack of fluoride in Germany, may explain some of the observed differences. Oral hygiene was practically absent, judged from the high prevalence of calculus found in both samples. However, problems with the preservation of these mineralised plaque deposits especially in the German samples hindered a more precise evaluation. Enamel hypoplasia was found in equal proportions in British and German samples, indicating similar levels of non-specific childhood stresses. In both countries, most disturbances had occurred in the same age category, between 1.5 and 2.0 years. However, problems with applying modern standards of dental growth to past individuals may not be appropriate. Nevertheless, it could be verified that childhood stress in both countries was highest at a similar time interval. Statistically significant differences in dental disease prevalence between females and males were only observed in one instance: British males had a significantly higher frequency of pulp exposure than British females. It is unclear why male pulp exposure was more prevalent and an analysis of dental attrition patterns may have provided some insight into this problem. However, dental attrition was already used to assess adult age and, therefore, hypothetical age-related changes of female and male attrition cannot be independently evaluated. For all dental diseases, with the exception of enamel hypoplasia which manifests itself in childhood, an age-related increase in disease prevalence was noticed, indicating accumulative processes of pathogen exposure. It would be tempting to use this increase in prevalence also as an indicator of correct age estimation, but regrettably circular argumentation renders this impossible. Nevertheless, in general German individuals displayed more dental disease when compared to the British samples.

7.4 Joint disease (arthropathies)

A similar age-related increase was found for joint disease prevalence, which was observed for osteoarthritis, degenerative disc disease and Schmorl's nodes. In all instances, prevalence was highest in the older age categories. Similar rates were found for British and German individuals with extra-spinal joint disease, although some joints were less often affected than others and sub-samples were not always large enough to allow for statistical testing. Similarly, no differences between the study samples were found in prevalence rates of degenerative disk disease and Schmorl's nodes. However, German individuals had significantly more spinal osteoarthritis and, especially, German males had the highest rates of all sub-samples. A higher male prevalence may be caused by sex-related labour division, but this does not explain why German males had a higher prevalence that their British counterparts, unless differences in agricultural practices may have existed between the two countries. Nevertheless, osteoarthritis may be caused by more than one factor and everyday 'wear-and-tear' is only one of them. Again, despite similar rates for DDD and Schmorl's nodes, German individuals had a higher prevalence of joint disease than British individuals.

7.5 Trauma

The prevalence of long bone fractures was similar in British and German individuals, although German skeletons showed more fractures per individual. In both countries long bone fractures were much more prevalent among males and since most fractures could have been the result of accidents, it can be concluded that men were more accident-prone, perhaps because they performed riskier tasks than females. The picture was less clear cut when non-long bone fractures of other postcranial bones were investigated: several fractures may have been caused by deliberate injuries and females and males alike were targeted. However, the number of this kind of fractures was too low to allow definite conclusions. A striking difference between the two study samples was found for cranial injuries caused by inter-personal violence, where German individuals and, especially, men were significantly more often affected. However, the nature of these violent attacks might have varied – warfare, intra-group fights or raids from neighbouring tribes would have been possibilities for sustaining these injuries. Spondylolysis is also of traumatic origin, but in combination with a congenital predisposition, and no difference in prevalence rates between the study samples, or women and men, were detected. Since the onset of this condition is in childhood, it is likely that similar levels of physical labour were performed by non-adults of both sexes.

Taking the high number of cranial injuries into consideration, German individuals were more likely to have experienced trauma than individuals from the British samples.

7.6 Non-specific infections (NSI)

Cases of non-specific infectious disease, both in the form of healed and unhealed lesions, occurred particularly often on the lower limb bones of male individuals from both countries. The location of these lesions and their predominance in male individuals suggests an activity-related traumatic origin, with men enduring more repetitive strain on their legs than women. Although no significant difference was found between British and German frequencies for chronic maxillary sinuses, German females had higher rates compared to German males. It was not clear to what extent chronic maxillary sinusitis was induced by upper respiratory tract infections or dental disease, although, for example, more elderly individuals also had a higher number of dental abscesses in combination with inflammatory responses of the maxillary sinuses. However, individuals might have suffered from both – respiratory infections and odontogenically induced maxillary sinusitis. Periostitis of the visceral surface of ribs was found to have similar prevalence rates in the study samples. The origins of this condition are likely to be lower respiratory tract infection, but a more specific infection, tuberculosis, may have been the cause. However, as no other skeletal changes associated with TB were found in the study samples, it may be concluded that this was not the causative factor. Nevertheless, only a few people infected with the *Mycobacterium* will develop skeletal changes and, even in the presence of bony reactions, these are difficult to differentiate from other infectious lesions. Endocranial lesions might also be caused by tuberculosis or they can be due to meningeal infections, induced by other infectious pathogens. There are problems with ascribing an ultimate cause to these changes using macroscopic studies. In the German samples more non-adult than adult individuals were affected and among them a high proportion of lesions were still active at their time of death. In contrast, only adult men from one British sample showed comparable endocranial lesions, making differences in the causative factor likely.

With similar frequencies for non-specific infections in both countries, it can be concluded that the study samples had a similar exposure to infectious pathogens. Additionally, in both counties similar proportions of individuals survived long enough to display signs of infection.

7.7 Congenital and developmental anomalies

Although British samples showed a higher prevalence of congenital and developmental anomalies, this difference was not statistically significant. Genetic proximity as well as environmental factors may lead to anomalies developing in the unborn child. One might conclude that both populations had a similar genetic susceptibility, but that environmental factors played a more important role, resulting in the higher variability among British samples, because these populations were from more diverse geographical areas, compared to the German individuals. However, the overall prevalence of congenital and developmental anomalies between the two countries was similar.

7.8 Metabolic disorders

Cribra orbitalia, a condition associated with childhood iron-deficiency anaemia was statistically more prevalent in the German samples, although in both countries non-adults were affected more often than adult individuals. As women and men had similar rates, it can be concluded that girls and boys were likewise similarly affected. Iron-deficiency anaemia may be induced by different aetiological factors, none of them mutually exclusive. Non-adults in both countries were significantly more often affected than adults and it appears that conditions leading to cribra orbitalia led to a higher mortality among children. However, porotic lesions of the orbital roof may remodel in adults, although higher rates in older adult individuals led to the conclusion that remodelling does not necessarily occur at a constant rate. Other metabolic diseases such as scurvy and rickets were not identified in the study samples and fractures, especially of vertebral bodies seen preferentially in elderly females, might have been induced by osteoporosis. Concentrating on iron-deficiency anaemia as an example of metabolic disorders in the study samples, again, German individuals were more often affected.

Finally, a comparative summary for each disease category is shown in Table 7.1. However, this table oversimplifies the complexity of specific conditions within each category. In four disease categories – dental disease, joint disease, trauma, and metabolic disorders – individuals from the German samples had higher prevalence rates, while in the remaining two categories – non-specific infections and congenital anomalies frequencies were similar between the two countries.

	British samples	German samples
Dental disease	↓	↑
Joint disease	↓	↑
Trauma	↓	↑
Non-specific infections	↔	↔
Congenital and developmental anomalies	↔	↔
Metabolic disorders	↓	↑

Table 7.1 Relative frequencies of pathological conditions in both pooled samples (↓=lower frequency, ↑=higher frequency, ↔=equal frequencies).

7.9 LIMITATIONS

In both countries, children displayed very few pathological conditions; non-adults were mainly affected by cribra orbitalia. However, since most diseases that affect the skeletal system are chronic in origin, children may have died before they could develop skeletal changes or they survived long enough to acquire bone alterations, but grew into adults, thus being absent from the non-adult record.

To return to the initial question of which pathological indicators of health and disease were prevalent in the early medieval study populations, a wide array of disease categories were found to be present. However, not all of these diagnoses were unequivocal and it has to be remembered that in palaeopathology a precise diagnosis is often impossible, while individual disease categories may be easier to identify (e.g., Miller *et al.*, 1996; Lovell, 2000). Nevertheless, some diseases may be included in several categories; for instance, spondylolysis is thought to have both a congenital and a traumatic origin. Additionally, it has to be borne in mind that most diseases are multi-factorial in origin and aetiology, thus resulting in multiple and sometimes contradicting interpretations. To complicate matters even further, an individual might have suffered from more than one disease, each of them maybe leaving similar skeletal changes. For example, were lytic lesions of the orbital roof caused by an expansion of the diploë or were these lesions caused by new bone formation? The latter feature itself might be indicative of different processes. New bone formation may be found as a reactive response to a non-specific infection or new bone can form subsequent to capillary bleeding caused by vitamin C deficiency. Potentially histological analysis can be used to differentiate between different diseases. Histology may also be helpful to differentiate between pathological bone changes and pseudopathology due to post-mortem damage (e.g., Jerusalem, 1955; Schultz, 2001). However, not all pseudopathological changes are detectable by histology. For example, skulls may become deformed due to heavy soil, which can be mistaken for a case of premature cranial synostosis or torticollis. This phenomenon was already observed by Wells (1967), who coined the term 'posthumous plagiocrany'. However, in population-based studies, neither histology nor radiology can be employed because of the destructive nature of the first and impracticalities of both techniques, since most research projects have to observe time and financial restrictions. Furthermore, in conventional radiography a change of 40-50 per cent in bone mineral density is needed before a pathological condition can be detected. Thus, many of the more subtle changes are missed. Additionally, superimposition of osteological structures that are created by reducing three-dimensional bones into two-dimensional radiographs can create problems in interpreting pathological conditions. Computer tomography may reduce some of these limitations. However, the power of the CT software to manipulate the electronic files has the potential to create features that are artefacts of the technology rather than biological differences that occur within the skeletal tissue. Another limitation is the cost of CT equipment and its maintenance and collaboration of radiology staff is needed to use the equipment when it is not needed for patients (Ortner, 2002).

The basis of palaeopathology is modern pathology. However, the majority of pathological changes manifest as soft tissue changes and lesions of the skeletal system are extremely rare. Creel (1966: 83) concluded that, "The analysis of pathological changes affecting bone from past populations is therefore able to provide only a very imprecise picture of their health." Other problems with using modern clinical data to diagnose ancient diseases have to be added. Modern diseases are influenced by various types of therapeutic intervention which may alter skeletal manifestations of that disease. The diagnosis of diseases in modern patients usually concentrates on soft tissue manifestations and skeletal lesions play a less important role. For example, iron-deficiency anaemia is diagnosed when blood iron levels are below normal, but clinicians would not radiograph their patient's orbital roofs to prove whether lytic lesions are manifest there.

In the current study, statistical testing was employed to verify whether differences in prevalence rates were due to chance or truly significant. However, not all results produced high enough numbers to provide meaningful sub-samples for statistical testing. In some instances, results just missed being statistically significant but since the cutting-off level was a subjective choice set at the 0.05 per cent level of confidence, results may be arbitrary as well.

Despite these problems with diagnosis and interpretation of pathological changes in past human skeletal remains, the systematic and population-based analysis of skeletal changes may provide an important window into the lives of these people because palaeopathology should not be seen only as a product of pathological processes but also as a phenomenon related to the interplay between demography and social, economic and cultural behaviour on the one hand and the environment on the other.

7.10 Recommendations for future work

It has been demonstrated that early medieval German populations displayed more pathological changes in four out of six disease categories. However, not all diseases encountered in the two countries could be included in the present study, because of a lack of precise diagnosis. For example, neoplastic disease would have been under-represented due to the lack of radiographic examination. Other diseases, such as tuberculosis, may have been present, but only DNA analysis would have indicated the presence of the tuberculosis bacterium (e.g., Brown, 2000). Future research into health and disease patterns, regardless of archaeological period and geographical area, may be better equipped to use improved diagnostic tools when methods become more widely available. However, since population-based studies are preferable to isolated case studies of few individuals, a compromise needs to be found. Furthermore, more environmental data would have been needed to interpret the obtained results on disease frequencies. With hindsight, it might have been better to select study populations with more data available on their environment, including, for example, soil and water analyses as well as isotope studies to reconstruct dietary habits. Further studies are clearly needed to understand past peoples' reactions to pathogens not only in the early medieval period

CHAPTER EIGHT

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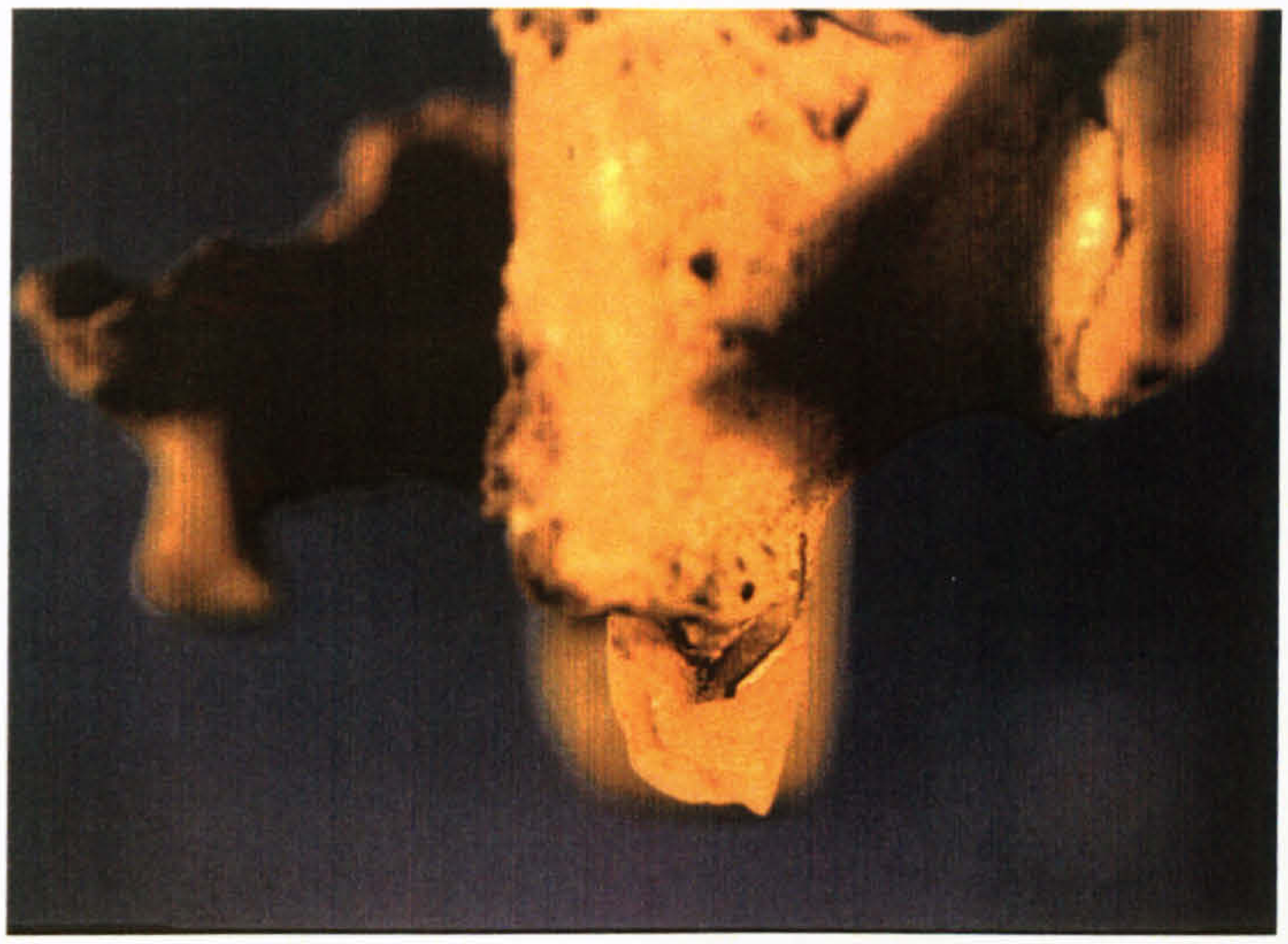
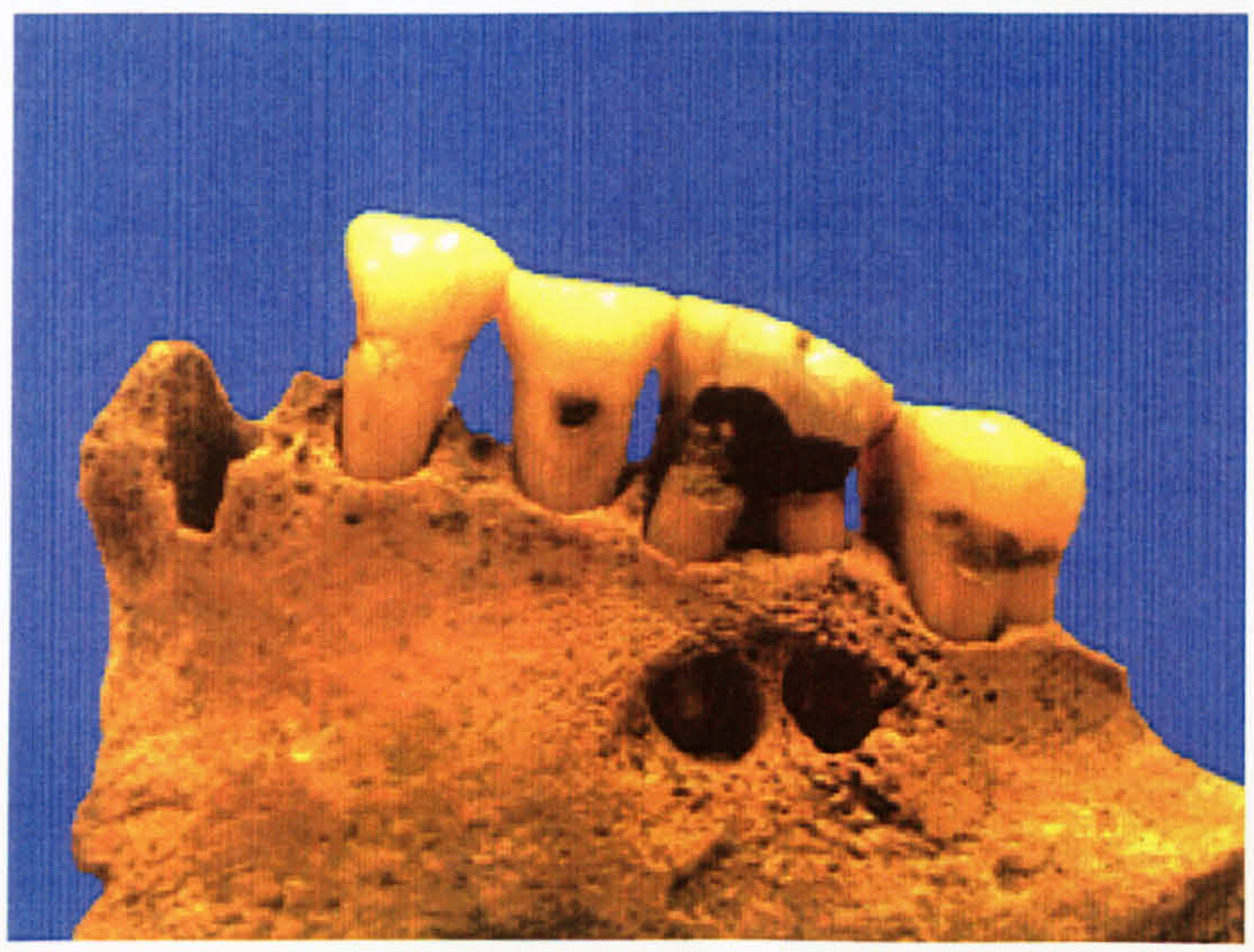


1. NU109 Large calculus deposit on left maxillary second molar.

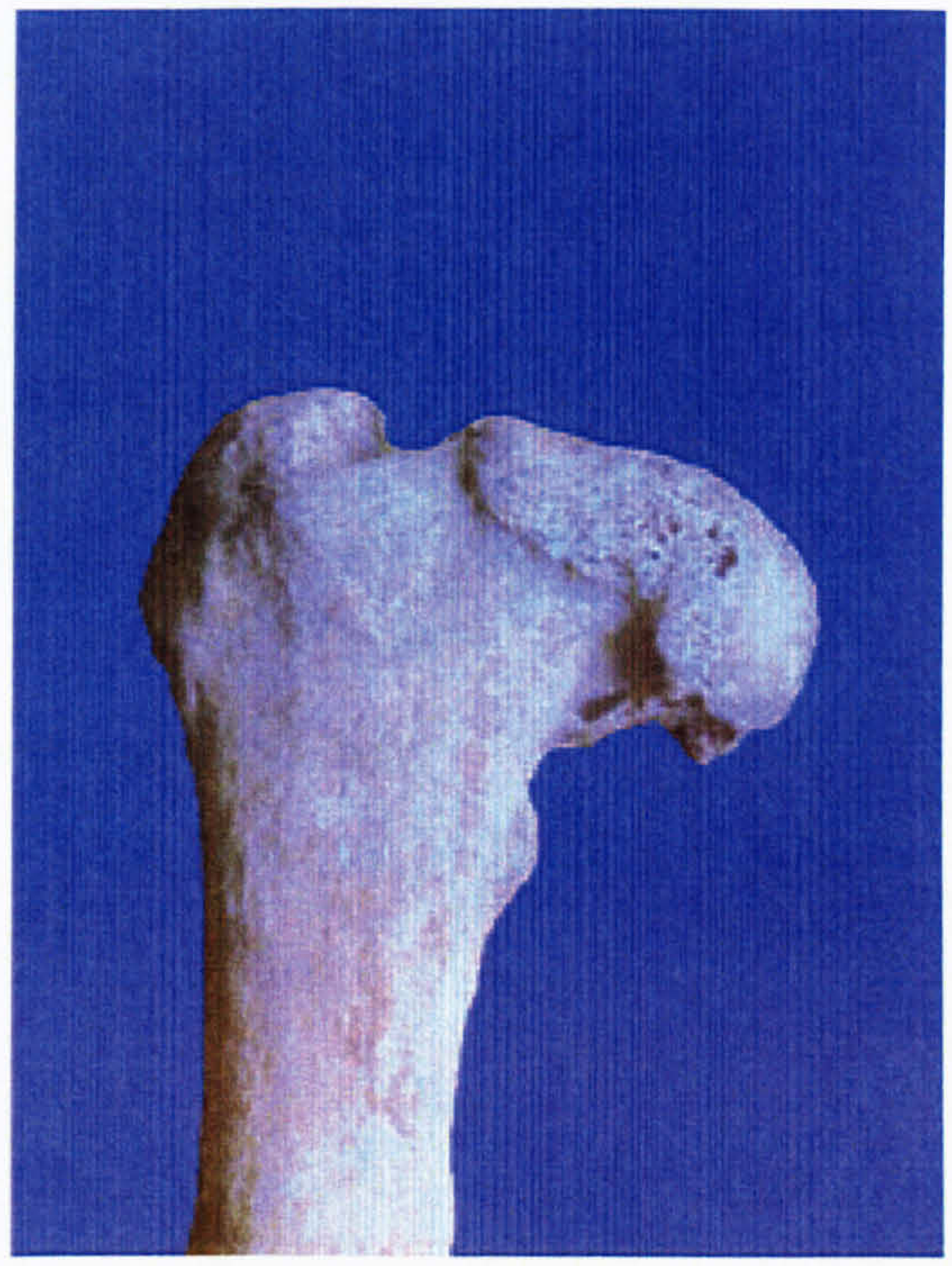


2. CS168 Left mandibular first molar with carious cavity and two external sinuses indicating a periapical lesion.

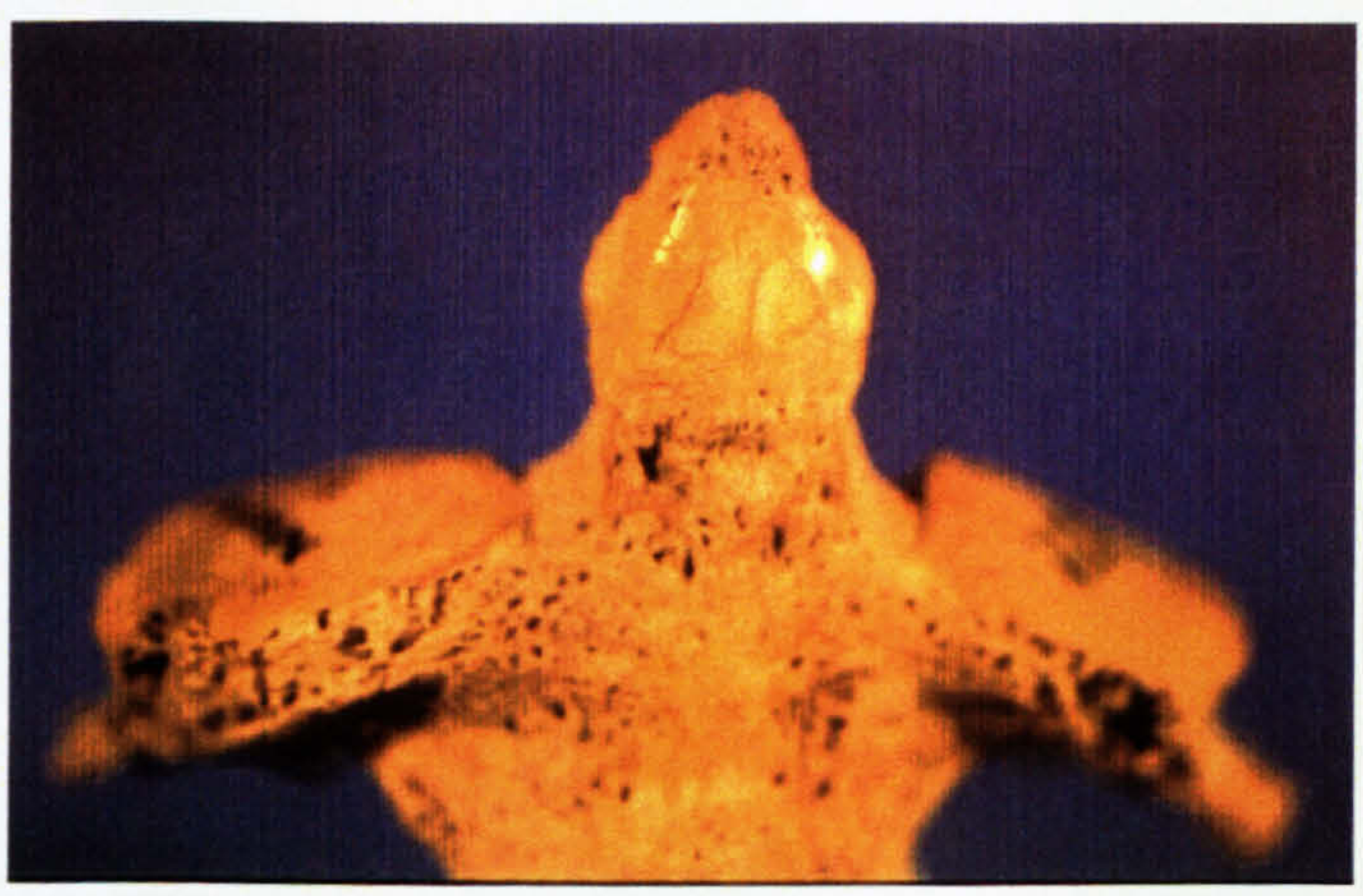
3. NE145 Mandible with ante-mortem loss of left first molar, both mesial incisors, right second premolar, right first and third molars.

4. PL16A Mandibular left canine with hypoplastic defect.

1. NE8-1 Osteoarthritis of right third metacarpal – eburnation and pitting of head.



2. CS89 Osteoarthritis of right proximal femur – femoral head mushroom-shaped, new bone formation at margins and some pitting.



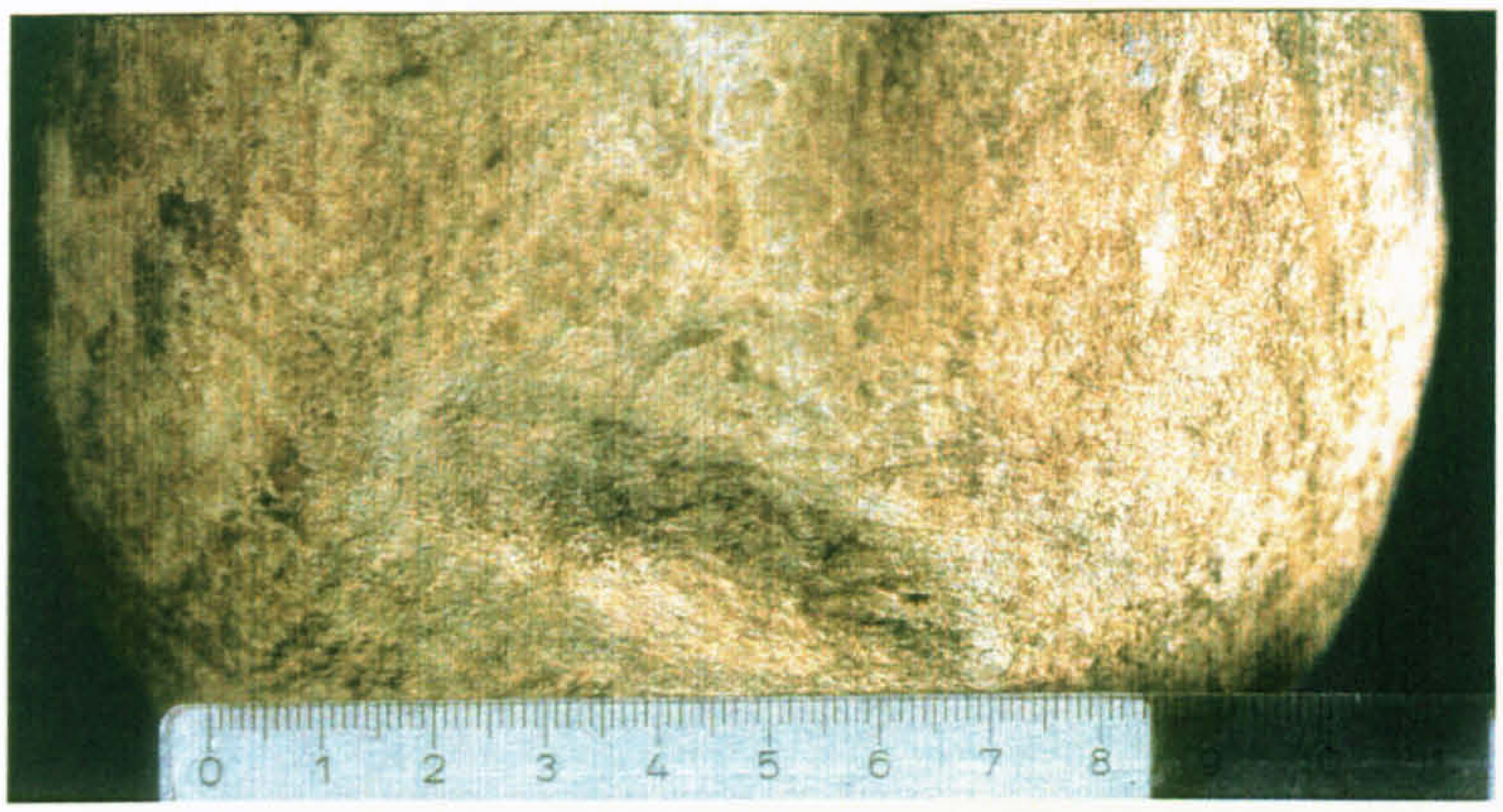
3. NU31 Osteoarthritis of second cervical vertebra – eburnation on anterior articular facet (dens axis).

4. PL82 Third cervical vertebra – left inferior articular facet with eburnation and grooves.

1. PL116 Right clavicle with pseudoarthrosis.

2. NE61-1 Right tibia with healed fracture of distal diaphysis.

3. PL116 Healed fractures of left second and third metatarsals, and second metacarpal (from right to left).

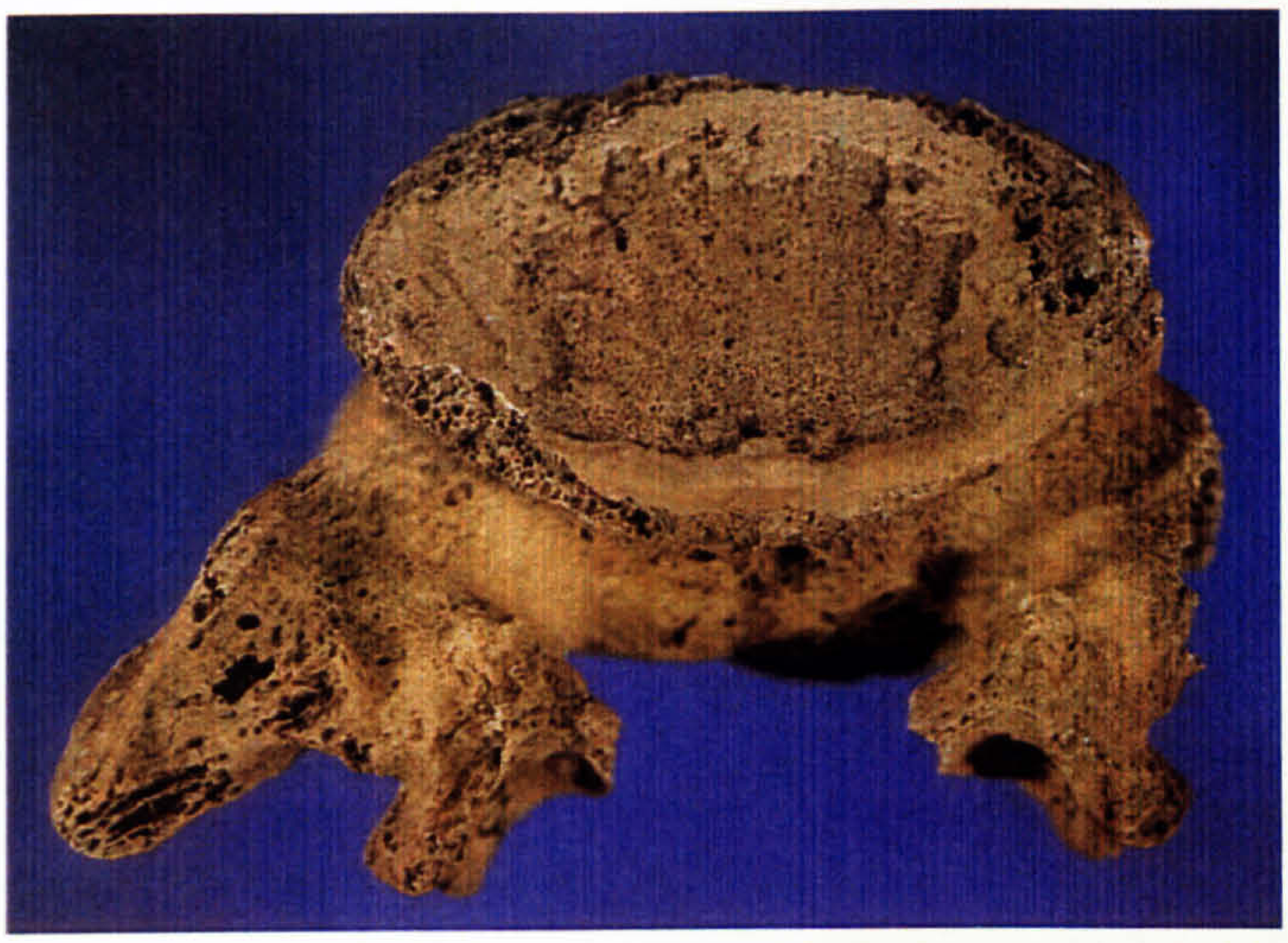


1. NE118 Left parietal bone with healed depression fracture caused by blunt force injury.

2. NU208-1 Left frontal bone with healed sharp force injury.

3. PL120 Right superior orbital margin with healed sharp force injury.

4. NE78-1 Left parietal bone with unhealed sharp force injury.



1. NU169 Fifth lumbar vertebra with separation of inferior articular facets.

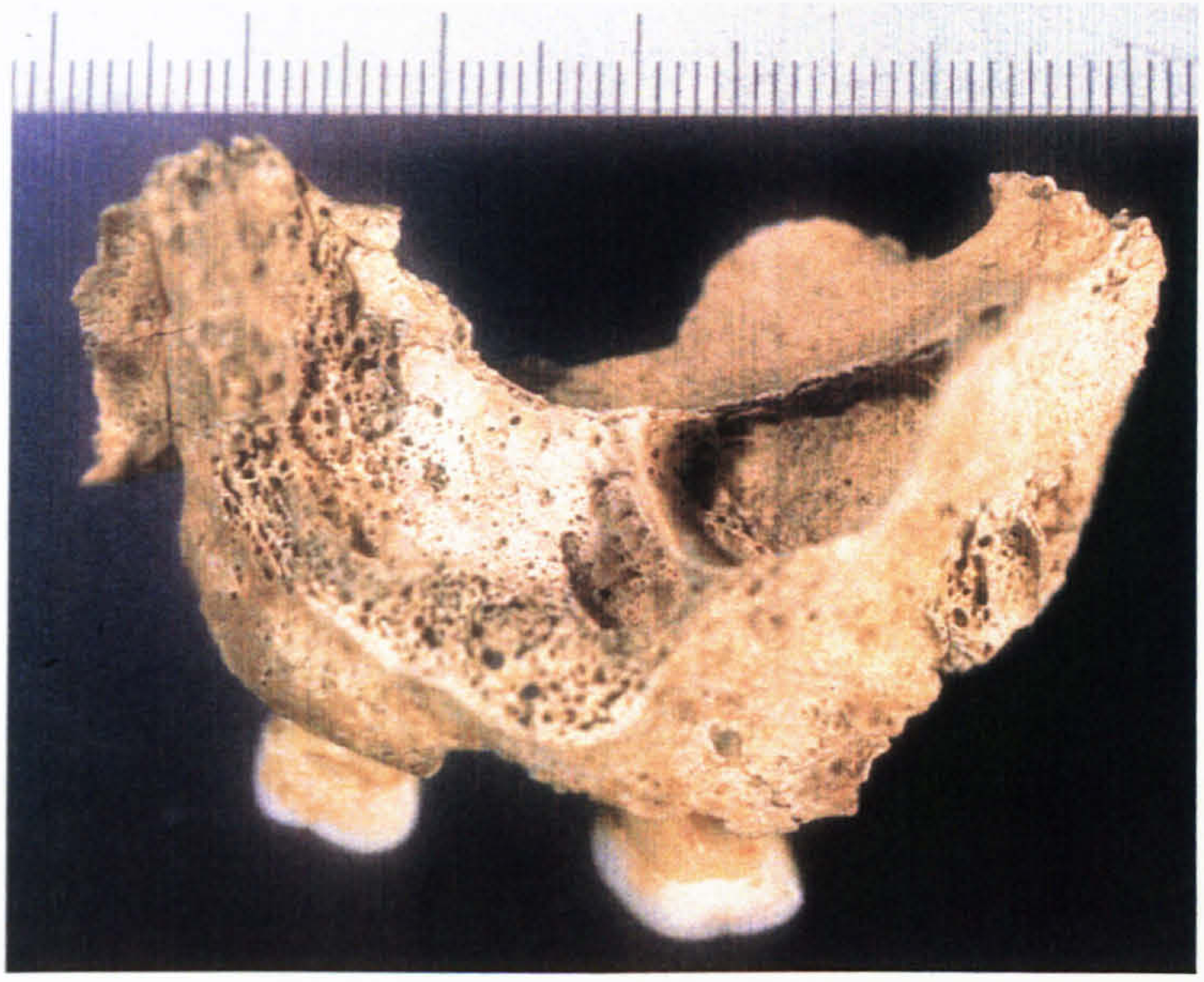
2. CS33B Fifth lumbar vertebra with separation of left inferior facet - partial spondylolysis, right side lost post-mortem.

1. AP 152 Left fibula with post-mortem break of distal diaphysis showing three concentric layers of new bone formation.

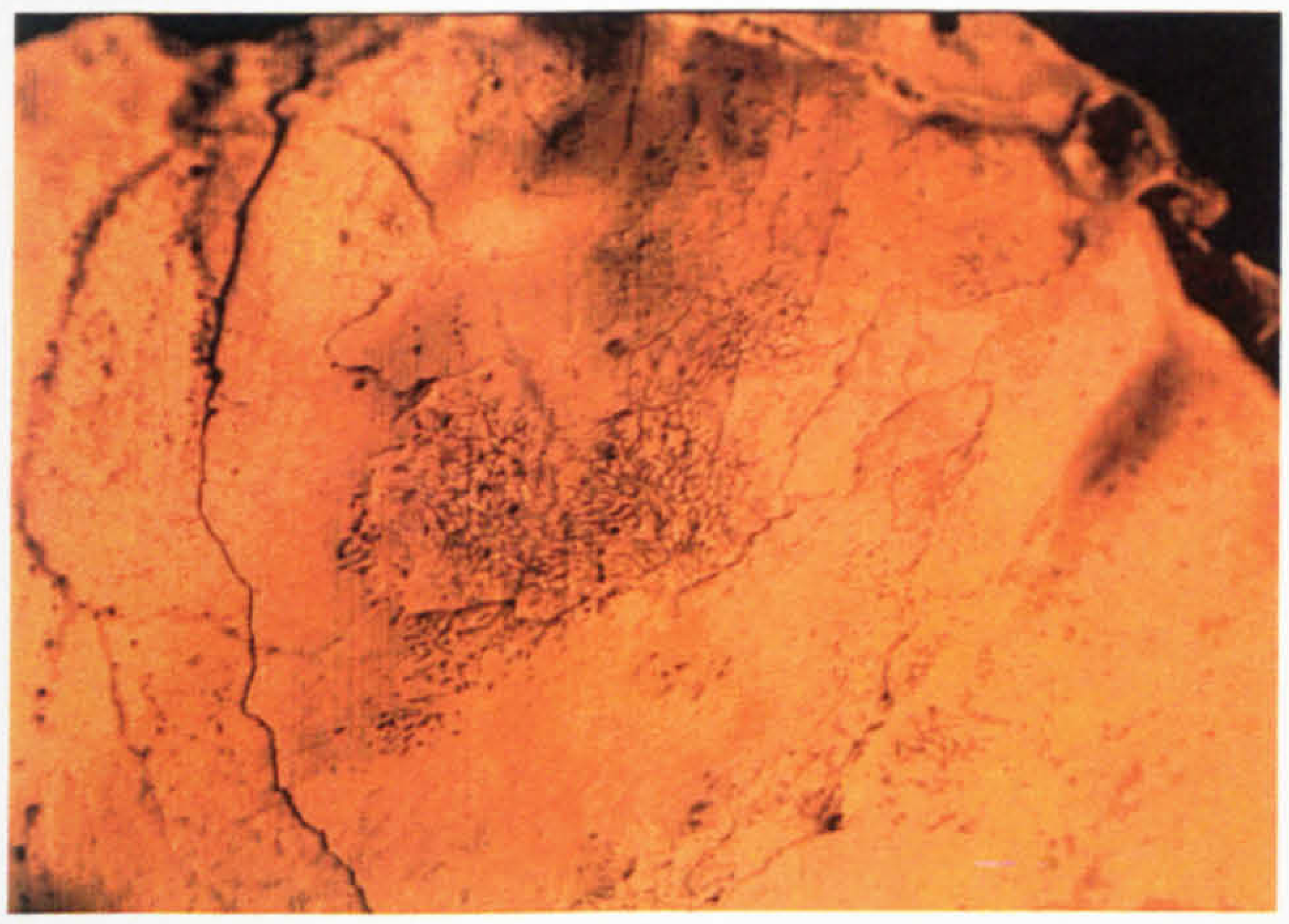
2. AP152 Right-sided ribs with remodelled new bone formation.

3. NU139 Left tibia with woven pitted new bone formation (active lesion).

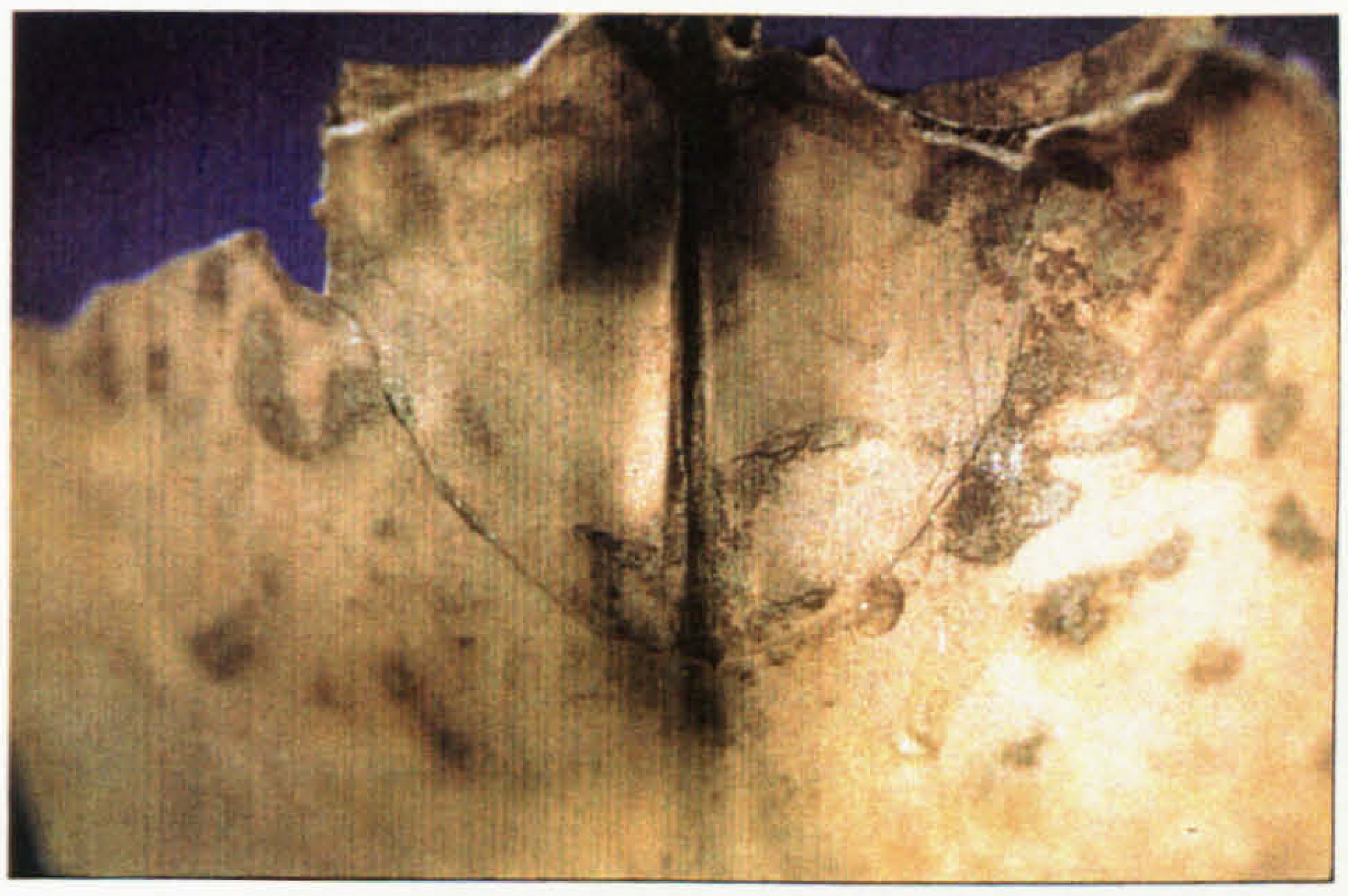
4. NU144-1 Left femur with woven pitted and remodelled new bone formation (mixed lesion).



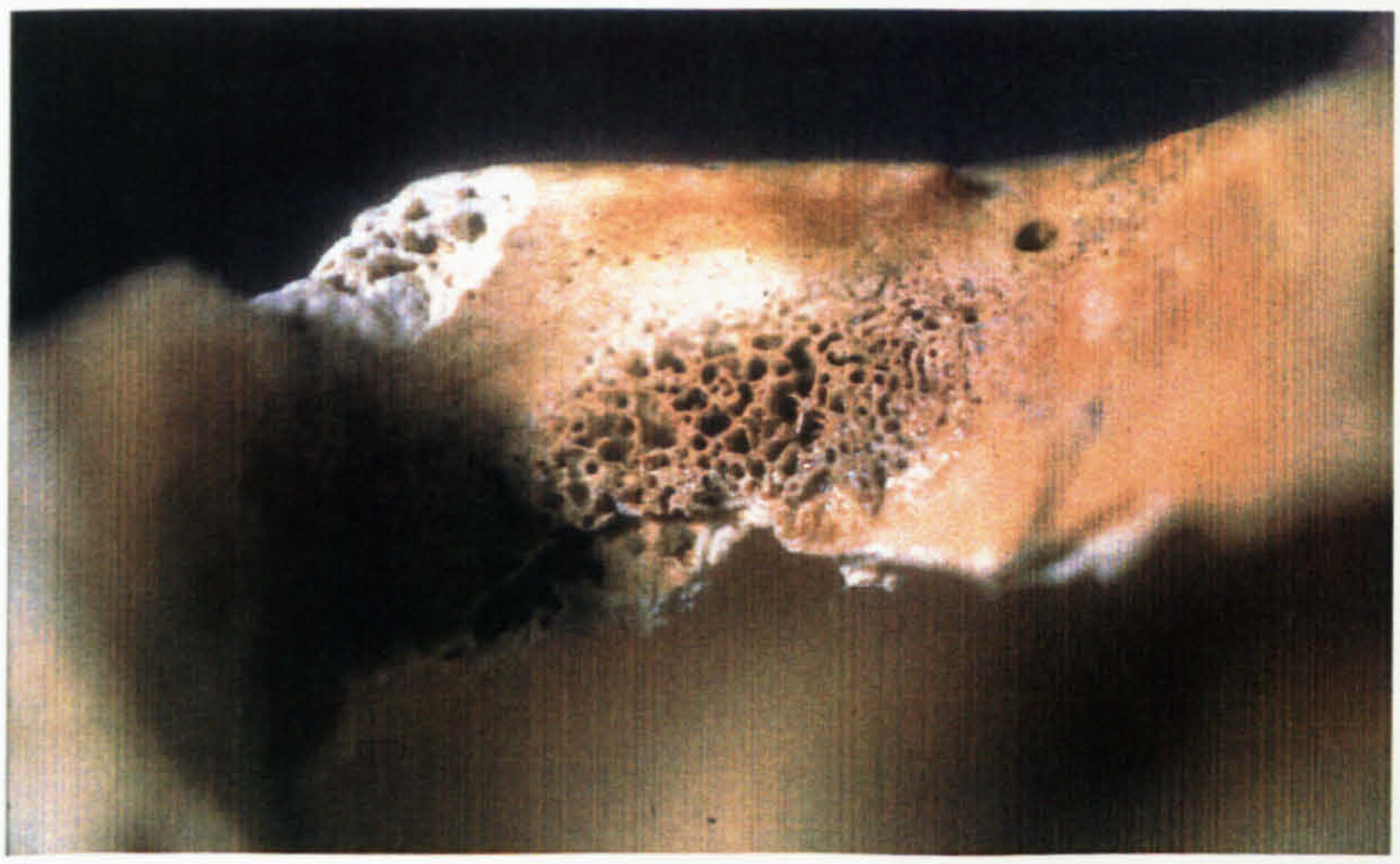
1. NE68 Right maxillary sinus – wall and antrum covered with remodelled porous new bone formation.



2. NU116 Vessel impressions on internal aspect of frontal bone.



3. PL6 Patches of woven pitted new bone formation on internal frontal.



4. NE150 Right orbital roof with coalescent active pitting and raised trabeculae (stage IV).

APPENDIX C

Skeletal Recording Form/Summary

Site:

Skeleton No.:
Archaeological date: 5th-8th

Sex:

Age:

Stature (cm): (element)

Preservation: Teeth (enamel)
Bones (cortex)

Fragmentation:

- Bones present:

- Additional bones:

Skeletal pathologies:

Dentition:

8 7 6 5 4 3 2 1	1 2 3 4 5 6 7 8	e d c b a	a b c d e
8 7 6 5 4 3 2 1	1 2 3 4 5 6 7 8	e d c b a	a b c d e

Dental pathologies:

Visual recording (photograph/sketch/x-ray):

Additional remarks:
Grave catalogue:

Site: Skeleton No.:

Skeletal Recording Form/Details

Tabular inventory of bones present:

Cranial Bones and Joint Surfaces

	L(eft)	R(ight)	U(nsided)		L	R	U
Frontal				Sphenoid			
Orbital roof				Zygomatic			
Front sinus				Maxilla			
Parietal				*Max. sinus*			
Occipital				*Palate*			
Occ. condyle				Mandible			
Temporal				*Condyle*			
PPT				Hyoid			
Mand. fossa				Th. cartilage			

Occ. condyle=Occipital condyle
PPT=Petrous part of temporal
Mand. fossa=Mandibular fossa
Max. sinus=Maxillary sinus
Th. cartilage=Thyroid cartilage

Postcranial Bones and Joint Surfaces

	L	R	U		L	R	U
Clavicle				Ischium			
Med. end				Pubis			
Lat. end				*Acetabulum*			
Scapula				*Auric. surf.*			
Acromion				Sacrum			
Glenoid f.				*Base*			
Manubrium				*Sacral facets*			
Clav. notch				*Sacro-iliac j.*			
1st costal n.				Patella			
Corpus				*Med. facet*			
Notch 2-7				*Lat. facet*			
Ilium				Coccyx			

Med. end=Medial end
Lat. end=Lateral end
Glenoid f.=Glenoid fossa
Clav. notch=Clavicular notch
1st costal n.=1st costal notch
Auric. surf.=Auricular surface
Sacro-iliac j.=Sacro-iliac joint
Med. facet=Medial facet
Lat. facet=Lateral facet

Vertebrae (# present/# complete)

	Centre	Neural arch		Centra	Neural arch
C1			C3-7		
C2			T1-12		
			L1-5		

#=number
C=Cervical vertebra
T=Thoracic vertebra
L=Lumbar vertebra

Site: Skeleton No.:

Cervical vertebrae (articular facets)

No.	Facets				Bodies	
	Sup.		Inf.		Sup.	Inf.
	L	R	L	R		
1						
2						
3						
4						
5						
6						
7						

Sup.=Superior Inf.=Inferior

Thoracic vertebrae (articular facets)

No	Facets				Bodies		(Demi)facets				Facets	
	Sup.		Inf.		S.	I.	Sup.		Inf.			
	L	R	L	R			L	R	L	R	L	R
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

Sup.=Superior Inf.=Inferior
S.=Superior I.=Inferior

Lumbar vertebrae (articular facets)

No.	Facets				Bodies	
	Sup.		Inf.		Sup.	Inf.
	L	R	L	R		
1						
2						
3						
4						
5						

Sup.=Superior Inf.=Inferior

Site: Skeleton No.:

Ribs (individual) Ribs (grouped) # present/# complete

	L	R	U	Vis	L	R	U	Vis	Cartilage
1st									
Head									
Tubercle									
2nd									
Head									
Tubercle									
11th									
Head									
12th									
Head									

U=Unsided Vis=Visceral surface of rib

Long bones

	Diaphysis				Diaphysis		
L	PT	MT	DT	R	PT	MT	DT
Humerus				Humerus			
Radius				Radius			
Ulna				Ulna			
Femur				Femur			
Tibia				Tibia			
Fibula				Fibula			
Talus				Talus			
Calcaneus	.			Calcaneus			

PT=Proximal third MT=Middle third
DT=Distal third

Long bones (articular surfaces)

		L	R		L	R		L	R
Humerus	Head			Capitulum			Trochlea		
Radius	Head			Rad. tuber.			Art. scaph.		
	Art. luna.			Ulnar notch					
Ulna	Troch. notch			Radial notch			Head		
Femur	Head			Med. condyle			Lat. condyle		
	Facies patell.								
Tibia	Med. condyle			Lat. condyle			Prox. tibia/fib.		
	Dist. tibia/fib.			Tibia/talus					
Fibula	Prox. fib./tibia			Dist. fib./tibia			Fibula/talus		
Talus	Trochlea			Head			Medial tibia		
	Lateral fibula			Post. calc.			Medial calc.		
	Ant. calc.								
Calcaneus	Calc. tuber.			Post. talus			Medial talus		
	Ant. talus			Calc./cuboid					

Rad. tuber.=Radial tuberosity Art. luna.=Radius articulation with lunate
Art. scaph.=Radius articulation with scaphoid Troch. notch=trochlear notch of ulna

Site: Skeleton No.:

Rad. tub.=Radial tuberosity
Med. condyle=Medial condyle
Lat. condyle=Lateral condyle
Facies patell.=Patellar surface of femur
Prox. tibia/fib.=Articulation of proximal tibia with fibula
Dist. tibia/fib.=Articulation of distal tibia with fibula
Prox. fib./tibia=Articulation of proximal fibula with tibia
Dist. fib./tibia=Articulation of distal fibula with tibia
Post. calc.=Posterior calcaneal articular surface
Medial calc.=Medial calcaneal articular surface
Ant. Calc.=Anterior calcaneal articular surface
Calc. tuber.=Calcaneal tuberosity
Post. talus=Posterior talar articular surface
Ant. Talus=Anterior talar articular surface
Calc./cuboid=Articulation of calcaneus with cuboid

Hand bones (grouped) # present/# complete

Foot bones (grouped) # present/# complete

	L	R	U		L	R	U
# Carpals				# Tarsals			
# MCs				# MTs			
# Phal.				# Phal.			
Proximal				Proximal			
Medial				Medial			
Distal				Distal			

#=number of
MCs=Metacarpals
Proximal=Proximal phalanges
Distal=Distal phalanges
MTs=Metatarsals
Phal.=Phalanges
Medial=Medial phalanges

Carpals (articulations)

Scaphoid		Radius		Lunate		Trapezoid		Capitate							
L	R														
Lunate		Radius		Capitate		Triquetral		Scaphoid							
L	R														
Triquetral		Lunate		Pisiform		Hamate									
L	R														
Pisiform		Triquetr.													
L	R														
Trapezium		Scaphoid		Trapezoid		I. Mc.		II Mc.							
L	R														
Trapezoid		Scaphoid		II. Mc.		Trapezium		Capitate							
L	R														
Capitate		Scaphoid		Lunate		II. Mc.		III. Mc.		IV. Mc.		Trapezoid		Hamate	
L	R														
Hamate		Triquetr.		Capitate		IV. Mc.		V. Mc.							
L	R														

Triquetr.=Triquetral
II. Mc.=2nd metacarpal
IV. Mc.=4th metacarpal
I. Mc.=1st metacarpal
III. Mc. =3rd metacarpal
V. Mc.=5th metacarpal

Site: Skeleton No.:

Metacarpals (articulations)

I. Mc.	Dist.	Trapezium			
II. Mc.	Dist.	Trapezium	Trapezoid	Capitate	III. Mc.
III. Mc.	Dist.	Capitate	II. Mc.	IV. Mc.	
IV. Mc.	Dist.	Capitate	Triquetral	III. Mc.	V. Mc.
V. Mc.	Dist.	Triquetral	IV. Mc.		

Dist.=Distal articulation of 1st-5th metacarpals

Hand phalanges (articulations)

		I		II		III		IV		V	
PR	Prox.										
	Dist.										
IR	Prox.										
	Dist.										
DR	Prox.										

PR=Proximal row
IR=Intermediate row
DR=Distal row
Prox.=Proximal end
Dist.=Distal end
I-V=Ist-5th digit

Tarsals (articulations)

Cuboid	Calc.	Lat. cun.	IV. Mt.	V. Mt.	Navic.		
L R							
Navicular	Talus	Med. cun.	Inter. cun.	Lat. cun.	Cuboid		
L R							
Med. cun.	Navic.	Inter. cun.	I. Mt.	II. Mt.			
L R							
Inter. cun.	Navic.	Med. cun.	Lat. cun.	II. Mt.			
L R							
Lat. cun.	Navic.	Inter. cun.	Cuboid	II. Mt.	III. Mt.	IV. Mt.	
L R							

Calc.=Calcaneus
Lat. cun.=Lateral cuneiform
I. Mt.-V. Mt.=1st-5th metatarsals
Navic.=Navicular
Med. cun.=Medial cuneiform
Inter. Cun.=Intermediate cuneiform

Metatarsals (articulations)

I. Mt.	Dist.	Med. cun.			
II. Mt.	Dist.	Med. cun.	Inter. cun.	Lat. cun.	III. Mt.
III. Mt.	Dist.	Lat. cun.	II. Mt.	IV. Mt.	

Site: Skeleton No.:

IV. Mt.	Dist.		Cuboid		Lat. cun.		III. Mt		V. Mt.	
V. Mt.	Dist.		Cuboid		IV. Mt.					

Dist.=Distal articulation of 1st-5th metatarsals

Foot phalanges (articulations)

		I		II		III		IV		V	
PR	Prox.										
	Dist.										
IR	Prox.										
	Dist.										
DR	Prox.										

PR=Proximal row IR=Intermediate row
DR=Distal row Prox.=Proximal end
Dist.=Distal end I-V=Ist-5th digit

Sex determination/adults:

Sex-diagnostic characteristics: Pelvis			
Ventral arc		Acetabulum	
Subpubic concavity		Iliac crest	
Subpubic angle		Obturator foramen	
Ischiopubic ramus ridge		Arc compose	
Auricular surface		Sacral alae	
Preauricular sulcus		Anterior sacral curvature	
Ischial tuberosity		Sacral auricular surface	
Greater sciatic notch		Overall sex: Pelvis	

Sex-diagnostic characteristics: skull			
Glabellar profile		Zygomatic process	
Supraorbital ridge		Nuchal area	
Orbital margins		External occipital protuberance	
Suprameatal crests		Mental eminence	
Mastoid process		Lower margin of mandible	
Internal acoustic meatus		Gonion	
Zygomatic bone		Overall sex: Skull	

Sex-diagnostic characteristics: metrical data					
	L	R		L	R
Humeral head diameter			Femoral bicondylar width		
Femoral head diameter			Scapular glenoid fossa width		
Radial head diameter			Clavicle max. length		
			Overall sex: metrics		

Site: Skeleton No.:

Age determination/adults:

Dental attrition I (Brothwell, 1981):

M3	M2	M1	M1	M2	M3	

Dental attrition II (Miles, 1963):

M3	M2	M1	M1	M2	M3	

Ectocranial suture closure (Meindl and Lovejoy, 1985)							
Site	Score	Site	Score	Site	Score	Site	Score
1		2		3		4	
5		6		7		8	
9		10		=			
Mean age		Mean Deviation		Range			

Pubic symphysis (Brooks and Suchey, 1990):
Auricular surface (Lovejoy *et al.*, 1985):
Sternal end of ribs (Loth and İşcan, 1989):

Age determination/non-adults and young adults:

Epiphyseal union (Gray, 1998):
Dental development (Smith, 1991, Moorrees *et al.*, 1963a; 1963b):
Long bone length (Hoppa, 1992):

Foetal age determination:

Long bone length (Scheuer *et al.*, 1980)
Pars basilaris (Scheuer and MacLaughlin-Black, 1994)
Development of temporal bone (Curran and Weaver, 1982)

Age category:

Site: Skeleton No.:

Long bone measurements (cm):

Max. length	L	R
Femur		
Tibia		
Fibula		
Humerus		
Radius		
Ulna		

Stature estimation (cm) after Trotter (1970):

Skeletal pathologies:

Joint disease: spinal/extra-spinal DJD/DDD (degenerative joint disease/degenerative disc disease)

- OA (Osteoarthritis: eburnation, porosity, osteophytes, contour change)
- SN (Schmorl's nodes)
- Other (Ankylosing spondylitis, DISH, rheumatoid arthritis, gout)

Trauma:

- Fractures (cranial/post-cranial)
- Fracture complications (non-union, osteomyelitis/periostitis, secondary arthritis)
- Spondylolysis
- Spondylolisthesis
- Myositis ossificans
- Exostoses
- Trepanation
- Amputation
- Artificial deformation of skull

Infectious disease

Non-specific infection:

- Periostitis/Osteomyelitis/Osteitis
- Maxillary sinusitis
- affected bone and side
- location
- type of bone formation (woven, lamellar, mixed)
- character (pitted, striated, plaque-like, mixed)
- size (in mm)

Specific infection:

- Tuberculosis
- Leprosy
- Treponemal disease

Site: Skeleton No.:

Stress indicators
- Iron deficiency anaemia
  - Cribra orbitalia
  - Porotic hyperostosis
- Enamel hypoplasia (see dental disease)

Circulatory disease
- Osteochondritis dissecans

Congenital and developmental disorders
- Sacralisation
- Lumbarisation
- Spina bifida occulta
- Premature cranial synostosis/microcephalus/hydrocephalus
- Cleft palate
- Achondroplasia
- Congenital dislocation of the hip

Endocrine disease
- Osteoporosis (Colles and femoral neck fractures)
- Hyperostosis frontalis interna
- Pituitary dwarfism

Metabolic disease
- Vitamin C deficiency
- Vitamin D deficiency

Neoplastic disease
- malignant neoplasms
- benign neoplasms

Permanent and deciduous dentition: Inventory and pathology

Right Maxilla								Left Maxilla							
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
Right Mandible								Left Mandible							

Permanent dentition

Site: Skeleton No.:

Right Maxilla								Left Maxilla							
			e	d	c	b	a	a	b	c	d	e			
			e	d	c	b	a	a	b	c	d	e			
Right Mandible								Left Mandible							

Deciduous dentition

Teeth present		Teeth erupted	
Roots only		AMTL	
Teeth with caries		Caries lesions	
Abscesses		Enamel hypoplasia	
Calculus			

AMTL=Ante-mortem tooth loss

Dental disease: Details

Caries: (Lukacs, 1989)

Tooth	Size (mm)	Position

Enamel hypoplasia

Calculus

Periodontal disease

Abscesses: internal/external sinus

Anomalies (dental crowding, tooth rotation etc.)

Mean crown height (mm):

Right Maxilla								Left Maxilla							
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
Right Mandible								Left Mandible							

Permanent dentition

Comments:

APPENDIX C

Appendix C1-3 is stored on CD-ROM. The files contain information on the demographic structure of each sample (C1), long bone measurements used for adult stature calculation (C2), dental diseases (C3) and spinal joint disease (C4). However, extra-spinal joint disease is given in paper format as Appendix C4, Tables 1-6.

Information is listed in the following order: site, sex and age, followed by a description of the skeletal element involved and/or a description of the pathological condition. Within each table, individuals were listed by site (**AP**=Apple Down, **CS**=Castledyke South, **NT**=Norton, **NE**=Neresheim, **NU**=Nusplingen and **PL**=Pleidelsheim), although when a disease affected a large number of individuals, tables for each sample were constructed separately. Furthermore, individuals from each sample are listed by sex (**N/D**=adult of undetermined sex, **F**=female, **SA**=subadult, **M**=male) and age category. All age categories are given in years, and months are indicated by **m**. The following additional abbreviations have been used in this appendix: **L**=left, **R**=right; in combination with a number the letters **C**, **T** and **L** denote specific cervical, thoracic and lumbar vertebra, while **S** combined with a number describes a specific sacral segment. **NBF** was used to abbreviate new bone formation.

APPENDIX C4 EXTRA-SPINAL OSTEOARTHRITIS

No.	Sex	Age	Skeletal element
AP23	F	26-35	R acetabulum, two L ribs
AP44	F	26-35	R femoral head
AP115B	F	26-35	R distal radius
AP120	F	26-35	L intermediate foot phalanx
AP175A	F	26-35	Three L and two R ribs, both femoral heads
AP14	F	36-45	Two L and one R ribs
AP17	F	36-45	1st metacarpals and hand phalanges
AP32	F	36-45	L 1st metacarpal, foot phalanges, both acromial clavicles and acromia, patellae
AP33	F	36-45	Temporo-mandibular joints
AP48	F	36-45	L acromial clavicle
AP55	F	36-45	L acromial clavicle, both 1st ribs, two L ribs, R 11th rib, both distal humeri and R proximal ulna, L distal radius, L lunate, R triquetral
AP71A	F	36-45	R sternal clavicle, R 1st rib
AP72	F	36-45	L temporo-mandibular joint
AP84	F	36-45	R 1st metacarpal, L sternal clavicle, L distal humerus and proximal radius, three L and two R ribs
AP107	F	36-45	Both acetabulae and R femoral head
AP151	F	36-45	L 3rd metacarpal, acromial clavicles, three L and two R ribs
AP153	F	36-45	L and R trapezium/scaphoid, L and R 1st proximal metacarpals, sternal and acromial clavicles, manubrium, both acetabulae and femoral heads, R distal femur and patella
AP78	F	45+	L temporo-mandibular joint, both acetabulae and femoral heads, three L and four R ribs
AP143	F	45+	Two hand phalanges, two L and one R ribs, both acetabulae and femoral heads, both distal femora and proximal tibiae
AP164	F	45+	R temporo-mandibular joint
AP163	M	16-25	L talus, calcaneus and cuboid
AP19	M	26-35	Both acetabulae and femoral heads
AP39	M	26-35	R sternal clavicle
AP68	M	26-35	Both femoral heads
AP118	M	26-35	Both acetabulae and femoral heads
AP67	M	36-45	L triquetral, L pisiform, R proximal foot phalanx
AP122	M	36-45	R scaphoid/distal radius, R trapezoid
AP125	M	36-45	L trapezium, both acetabulae and femoral heads
AP22	M	45+	Sternal clavicles and manubrium, acromia, L distal ulna
AP28	M	45+	Hand and foot phalanges, L cuboid and lateral cuneiform, L 1st and R 5th metatarsals, acromia, both femoral heads
AP31	M	45+	L 1st metatarsal, hand and foot phalanges, sternal clavicles and manubrium, R tarsals, temporo-mandibular joints
AP99B	M	45+	L 1st rib, three L and two R ribs
AP111	M	45+	L sternal clavicle and manubrium, both acetabulae

Appendix C4, Table 1 Apple Down. Individuals with extra-spinal joint disease.

No.	Sex	Age	Skeletal element
CS116	F	26-35	L acetabulum
CS167B	F	26-35	Glenoid fossae
CS23	F	36-45	R glenoid fossa, R scaphoid/trapezium/trapezoid, R 1st rib
CS30	F	36-45	Glenoid fossae, R humeral head, R 1st proximal hand phalanx and

			trapezium, both acetabulae
CS95	F	36-45	L distal radius
CS101	F	36-45	L acromial clavicle, L glenoid fossa, L acetabulum
CS138	F	36-45	L 1st metatarsal
CS160	F	36-45	Both acetabulae
CS163	F	36-45	Both acetabulae
CS169	F	36-45	L glenoid fossa
CS7	F	45+	Both distal femora
CS26	F	45+	L sternal clavicle
CS106	F	45+	R temporo-mandibular joint, R femoral head
CS115	F	45+	L distal radius, R acetabulum, R glenoid fossa
CS128	F	45+	L and R rib, 1st and 2nd L metatarsals, foot phalanx, R distal tibia and fibula, tali, acetabulae
CS132	F	45+	L 1st rib
CS137	F	45+	R acromion, medial clavicles, L acromial clavicle
CS166B	F	adult	Acromia, R humerus head, R femoral head, one R rib, R 11th rib, two L ribs, R trapezium/1st and 2nd metacarpals
CS185A	M	26-35	L acetabulum, L distal foot phalanx
CS19A	M	36-45	R 1st rib
CS36	M	36-45	L glenoid fossa
CS38	M	36-45	R 1st Mc and proximal 1st phalanx, glenoid fossae, manubrium, L proximal and distal ulna, both acetabulae
CS78	M	36-45	R temporo-mandibular joint, both acetabulae and femoral heads, patellae
CS89	M	36-45	R lunate, both acetabulae and femoral heads
CS92	M	36-45	R humeral head and glenoid fossa
CS93	M	36-45	Three R ribs
CS108	M	36-45	L acetabulum and femoral head, L rib
CS159	M	36-45	Distal radii, R scaphoid, hand phalanx
CS180	M	36-45	L acetabulum
CS6	M	45+	L clavicle (both articulations), R talus/calcaneus
CS63	M	45+	L distal femur, R medial cuneiform/navicular/1st metatarsal, R 2nd metatarsal
CS147	M	45+	1st and 3rd metacarpals, L lunate/radius, trapeziums, R triquetral, hand phalanges, R 2nd rib, both acetabulae and femoral heads, both distal ulnae
CS129	M	45+	1st R distal metatarsal and proximal 1st phalanx, L distal radius and ulna
CS208B	N/D	adult	L distal humerus
CS62	N/D	adult	R 4th metatarsal/lateral cuneiform, R distal femur and proximal tibia

Appendix C4, Table 2 Castledyke South. Individuals with extra-spinal joint disease.

No.	Sex	Age	Skeletal element
NT99	F	16-25	R glenoid fossa
NT1	F	26-35	One R rib
NT23	F	26-35	One L rib
NT52	F	26-35	L 1st and 2nd ribs, L and R rib, R 2nd rib
NT105	F	26-35	Both acetabulae and femoral heads, L glenoid fossa
NT9-1	F	36-45	Hand phalanx, two L ribs
NT49	F	36-45	R rib
NT70	F	36-45	Both acetabulae and R femoral head
NT84	F	36-45	L temporo-mandibular joint
NT113	F	36-45	L temporo-mandibular joint

NT7	F	45+	R acetabulum, five R ribs, R 4th metacarpal, L 1st metacarpal, hand phalanges, both capitates
NT106	F	45+	Both glenoid fossae
NT30	F	adult	R rib
NT37-1	F	adult	Two L ribs
NT47	F	adult	Both femoral heads and acetabulae
NT12-1	M	26-35	One unsided rib
NT25-1	M	26-35	L femoral head and acetabulum
NT18	M	36-45	L glenoid fossa
NT120	M	36-45	Both femoral heads and R acetabulum
NT17	M	45+	R femoral head
NT34-1	M	adult	L rib
NT112	N/D	16-25	Two R ribs
NT13	N/D	adult	Two L and two R ribs
NT111	N/D	adult	Both femoral heads

Appendix C4, Table 3 Norton. Individuals with extra-spinal joint disease.

No.	Sex	Age	Skeletal element
NE123	F	16-25	L femoral head
NE8-1	F	26-35	R 3rd metacarpal
NE9-1	F	26-35	R femoral head and both acetabulae, L 1st and 2nd metatarsals, foot phalanges, patellae
NE20	F	26-35	R acetabulum
NE42	F	26-35	L acromial clavicle, R 12th rib, R 1st metacarpal
NE49	F	26-35	One R rib
NE56-1	F	26-35	L 1st metacarpal, hand phalanx
NE57	F	26-35	L 1st rib
NE59	F	26-35	L rib
NE76	F	26-35	L rib
NE133	F	26-35	R sternal clavicle, R rib, proximal radii, acetabulae and femoral heads
NE140-1	F	26-35	R glenoid fossa
NE143	F	26-35	Temporo-mandibular joints
NE22-1	F	36-45	Two R ribs, L 12th rib
NE30	F	36-45	L 1st rib
NE67	F	36-45	L 1st rib
NE71	F	36-45	R aromion and acromial clavicle, acetabulae and femoral heads
NE111	F	36-45	Both acetabulae
NE135	F	36-45	L calcaneus
NE145	F	36-45	R temporo-mandibular joint, R 1st metacarpal, 3rd metacarpal and scaphoid, hand phalanx
NE3-2	F	45+	Three L and two R ribs
NE43	F	45+	Two L ribs and one R rib, both acetabulae
NE53	F	45+	R trapezium and trapezoid, R 1st metacarpal and 1st proximal phalanx, intermediate hand phalanges, R 3rd metacarpal, R cuboid
NE54	F	45+	R sternal clavicle; femoral heads and acetabulae
NE64	F	45+	L acromion, temporo-mandibular joints, L acetabulum
NE66	F	45+	Unsided glenoid fossa
NE81	F	45+	R acromion
NE106	F	45+	R proximal ulna
NE108	F	45+	R 1st metacarpal
NE125-2	F	adult	L temporo-mandibular joint
NE138	M	16-25	Calcanei

NE10	M	26-35	Both acetabulae
NE32	M	26-35	L sternal clavicle and manubrium
NE122-1	M	26-35	Two L and two R ribs
NE29	M	36-45	R acromion, R 11th rib
NE34	M	36-45	L femoral head and acetabulum, two L and two R ribs
NE61-1	M	36-45	R sternal clavicle, L femoral head and acetabulum, temporo-mandibular joints
NE68	M	36-45	L acromial clavicle and acromion, L 1st rib, one L and R rib
NE80	M	36-45	Acromial clavicles
NE87-1	M	36-45	Acromial clavicles and acromia
NE126-1	M	36-45	Two R ribs, both acetabulae and L femoral head
NE136	M	36-45	Acromial ends of clavicles and acromia, R femoral head and acetabulum
NE39	M	45+	Both acetabulae, L navicular, R distal ulna and radius
NE45	M	45+	Both acromia, R sternal clavicle, L 1st metacarpal, both scaphoids, R 1st metatarsal, L 4th and 5th metatarsals, 2 L ribs
NE79	M	45+	Acetabulae and femoral heads
NE102	M	45+	R distal ulna and radius, 1st ribs
NE109	M	45+	Both acetabulae
NE128	M	45+	R sternal clavicle, L acetabulum
NE141-3	N/D	adult	Both femoral heads

Appendix C4, Table 4 Neresheim. Individuals with extra-spinal joint disease.

No.	Sex	Age	Skeletal element
NU33	F	26-35	R distal femur and proximal tibia
NU86	F	26-35	Temporo-mandibular joints
NU90	F	26-35	R acromial clavicle
NU92	F	36-45	R temporo-mandibular joint
NU111	F	36-45	L 1st metatarsal, R distal radius, L patella
NU146	F	36-45	Both femoral heads
NU6	F	45+	R femoral head, L 2nd and 3rd metatarsals
NU112	M	26-35	R 11th rib
NU113	M	26-35	R distal humerus
NU83	M	36-45	R humeral head and proximal radius
NU99-1	M	36-45	L acromial clavicle, both femoral heads
NU185	M	36-45	R humerus, R acromial clavicle, intermediate phalanx, L temporo-mandibular joint, both acetabulae
NU201	M	36-45	L 1st metatarsal and 1st proximal foot phalanx, L medial cuneiform
NU212	M	36-45	L femoral head
NU12-1	M	45+	Rib, L acromial clavicle, R acromion
NU47	M	45+	L humerus
NU173	M	45+	Acromial clavicles, both acetabulae
NU211	M	45+	Both sternal and acromial clavicles, R acromion, R acetabulum both femoral heads, R patellar surface of femur, L 3rd metacarpal
NU257	M	45+	L temporo-mandibular joint
NU131	M	adult	R 4th metacarpal, R distal humerus and distal ulna
NU144-1	M	adult	L cuboid, R calcaneus
NU213-2	M	adult	Tali, L calcaneus and L cuboid

Appendix C4, Table 5 Nusplingen. Individuals with extra-spinal joint disease.

No.	Sex	Age	Skeletal element
PL45	F	26-35	R rib
PL65	F	26-35	Both femoral heads, R patellae
PL49	F	36-45	1st ribs
PL61	F	36-45	Both acetabulae
PL66	F	36-45	Acetabulae, sternal clavicle, temporo-mandibular joints
PL81	F	36-45	L 12th rib
PL115	F	36-45	Both 1st ribs, 2 L and 2 R ribs
PL141	F	36-45	R 4th metacarpal
PL59	F	45+	L 1st metatarsal
PL9	F	adult	R proximal radius
PL35	F	adult	R cuboid/lateral cuneiform
PL110	F	adult	R 11th and 12th ribs
PL103	M	26-35	R 1st metacarpal, L talus and navicular
PL42	M	36-45	L rib, R acromion
PL83	M	36-45	Ankylosis of L navicular/intermediate/lateral cuneiforms; L 1st, 2nd and 3rd metatarsals
PL90	M	36-45	Femoral heads
PL91	M	36-45	R cuboid/calcaneus, R talus
PL113	M	36-45	Acromial clavicles, distal ulnae, both femoral heads, L rib, R 1st metacarpal
PL116	M	36-45	R distal humerus and proximal radius
PL60	M	45+	L talus and calcaneus
PL79	M	45+	L rib, sternal clavicles, humeral heads, both acetabulae and L femoral head
PL111	M	45+	L 1st metatarsal and proximal foot phalanx
PL10	M	adult	L talus/navicular joint

Appendix C4, Table 6 Pleidelsheim. Individuals with extra-spinal joint disease.

No.	Sex	Age	Description
AP19	M	26-35	R fibula, proximal third of diaphysis with healed oblique fracture. No angulation but fine callus formation with remodelled pitting measuring 10 cm in length, spanning from supero-medial to infero-anterior direction
AP39	M	26-35	R femur, proximal third of diaphysis with healed oblique fracture. Slight posterior angulation, but callus smoothly remodelled on anterior aspect. On posterior side small exostoses and on middle third of diaphysis – medial aspect – larger exostosis (length=13 mm, height=6.0 mm)
AP118	M	26-35	L clavicle, middle third of diaphysis with healed oblique fracture. Lateral aspect angulated in inferior direction
AP126	M	26-35	R fibula, middle diaphysis with healed fracture. No angulation, shortening not measurable; large irregular callus (3.5x5.5 cm) but no signs of infection
AP138A	M	36-45	L clavicle, middle third of diaphysis with healed oblique fracture. Overlap of ca. 2.5 cm – lateral part bowed more in posterior direction than R side
AP12B	M	45+	L clavicle, middle third of diaphysis with healed oblique fracture. Marked angulation – lateral end displaced in inferior direction
AP28	M	45+	R clavicle, middle diaphysis with healed transverse fracture. Overlap=2.0 cm. Lateral part with ca. 45° inferior rotation
CS167B	F	26-35	R fibula, distal third of diaphysis with healed fracture. Ca. 7 cm slight thickening of diaphysis (L=14.2 mm, R=17.2 mm antero-posterior width) with remodelled pitted and striated new bone formation on medial aspect. Slight anterior angulation and minimal lateral rotation. No shortening
CS115	F	45+	L radius, middle third of diaphysis with healed spiral fracture. Shortening by 2.0 cm (L=23.7 cm, R=25.7 cm) and medial displacement of distal part. Callus mostly remodelled. Circular sinus on distal lateral margin of L radius (3.6 mm) surrounded by small patch of remodelled pitted new bone formation. Eburnation on L glenoid fossa (inferior margin), marginal osteophytes and irregular surface. L humeral head flat with broad rim of marginal osteophytes on anterior aspect. L distal ulna with eburnation, porosity and contour change, L radius – distal ulnar facet with eburnation. L triquetral with eburnation on articulation with lunate. L lunate grooved eburnation on articulation with radius
CS51	M	26-35	R clavicle, distal third of diaphysis with healed fracture. Ca. 30° inferior angulation of distal part with slight postero-inferior rotation. Surface of superior aspect irregular, with 'blown-up' appearance, but inferior aspect completely smooth. No pitting or other signs of infection

CS93	M	36-45	L clavicle, middle third of diaphysis with healed oblique fracture. Overlap (ca. 3.3 cm), no rotation but more angulated than R clavicle leading to shortening of bone. On anterior aspect of lateral diaphysis three irregular exostoses (width ca. 4.0 mm, length ca. 5.0 mm). L ulna, middle third of diaphysis with healed fracture. Remodelled tapering callus on all aspects (2.7 cm length). No angulation or rotation. Porous woven new bone formation on anterior and lateral aspects of proximal and middle third of diaphysis, extending from anterior margin of inferior trochlear facet to callus on anterior aspect. Medial aspect with some porous woven new bone formation on middle aspect of diaphysis
CS180	M	36-45	L clavicle, middle third of diaphysis with oblique fracture. Non-union but ca. 3.0 cm of woven porous new bone formation on antero-inferior aspect, nutrient foramen enlarged. Post-mortem damage of fracture site – distal part not recovered
CS100	M	45+	L fibula, proximal third of diaphysis with healed oblique fracture. Large (length=5.5 cm) remodelled callus with some spicules on lateral aspect – two remodelled sinus-like canals on postero-lateral border; no angulation or rotation
CS129	M	45+	R clavicle, middle third of diaphysis with oblique fracture. Non-union of fractured parts (pseudoarthrosis)
CS147	M	45+	R clavicle, middle third of diaphysis with healed fracture. Some overlap (ca. 2.0 cm), leading to shortening (L clavicle not measureable) and ca. 5° superior rotation of distal fragment. Smoothly remodelled callus. Porosity and contour change of medial articular facet
NT23	F	26-35	R clavicle, middle third of diaphysis with healing oblique fracture. Fracture line surrounded by woven, grey (active) new bone formation (covering an area of at least 5 cm). Amount of overlap not measurable due to post-mortem damage (at least 1.5 cm). No angulation but almost straight appearance of diaphysis due to rotation (ca. 45° in anterior direction)
NT91	M	16-25	R femur, middle third of diaphysis with healed oblique fracture. Overlap 8.1 cm. Medio-lateral displacement and antero-posterior bowing of diaphysis. No secondary infection or arthritis, but shortening and depression of femoral neck (*coxa vara*)
NE5	F	26-35	R tibia, middle third of diaphysis with healed fracture. Slight antero-posterior bowing of shaft, no callus visible but small exostosis on medial aspect of fractured area of tibia. R tibia slightly longer than L R fibula, middle third of diaphysis with healed fracture. Slight antero-posterior bowing, no callus visible. Possible shortening could not be measured due to post-mortem damage
NE9-1	F	26-35	L radius, distal third of diaphysis with healed oblique fracture. Lateral dislocation of distal fragment, with shortening (R=23.5 cm, L=22.3 cm) and irregular callus with some remodelled pitting
NE30	F	36-45	L tibia, middle third of diaphysis with healed fracture. Remodelled callus (4.0x3.0 cm), no pitting, but anterior angulation (ca. 15°). L fibula, middle third of diaphysis with healed fracture. Slight shortening due to overlap – proximal fragment healed back on lateral aspect of distal fragment (2.0 cm overlap)
NE135	F	36-45	R fibula, middle third of diaphysis with healed fracture. Lateral bowing of proximal third of diaphysis and medial bowing of distal third of diaphysis
NE77	M	26-35	L radius, proximal third of diaphysis with healed fracture. Bowing in lateral direction with slight thickening

NE61-1	M	36-45	R tibia, distal third of diaphysis with healed oblique fracture. Ca. 4.5 cm overlap; angulation ca. 5° in posterior direction; 0 per cent apposition; ca. 8.0 cm superior to distal fragment callus with large sinus and smooth margins on anterior aspect (0.5x1.2 mm); on posterior aspect callus almost smooth on superior part, but three irregular shaped perforations on inferior part. Remodelled striated and pitted new bone formation indicative of healed infection
NE80	M	36-45	L clavicle, distal third of diaphysis with healed fracture. Acromial end angulated. R clavicle, distal third of diaphysis with healed fracture. Acromial end angulated. R radius, distal third of diaphysis with healed fracture. Slight posterior angulation and two bony ridges divided by small groove on medial aspect. L fibula, proximal third of diaphysis with healed fracture. No angulation or displacement; callus well remodelled; no sign of infection
NE97	M	36-45	L clavicle, middle third of diaphysis with healed oblique fracture. Poorly aligned with secondary osteoarthritis at sternal articulation – facet enlarged and pitted
NE102	M	45+	R radius, distal third of diaphysis with healed fracture. Slight medial angulation, with 100 per cent apposition; callus remodelled with slightly irregular lateral surface. Distal articulation of R radius – marginal lipping, especially on ulnar notch. R distal ulna with eburnation and contour change. R fibula, distal third of diaphysis with healed fracture. Anterior margin with remodelled callus and exostosis (1.6 cm length)
NE103-1	M	45+	L tibia, distal third of diaphysis with healed fracture. Slight anterior angulation, remodelled callus
NE109	M	45+	R radius, distal third of diaphysis with healed oblique fracture. distal third of diaphysis with slight angulation in posterior direction (no measurements possible – only diaphysis fragment present)
NU102	F	16-25	R femur, proximal epiphysis (neck) with healed fracture. Femoral head depressed and parallel with level of greater trochanter; superior aspect of neck almost vertical, some remodelled new bone formation on anterior aspect. Two remodelled sinuses on anterior collum (4.6x6.4 mm and 2.9x6.1 mm). Femoral head mushroom-shaped
NU45	F	26-35	L clavicle, distal third of diaphysis with healed oblique fracture. Slight shortening, no angulation
NU169	M	16-25	R ulna, proximal third of diaphysis with healed oblique fracture. Remodelled slightly irregular callus. No angulation or rotation. L fibula, middle third of diaphysis with healed fracture. Posterior angulation of distal part (ca. 30°)
NU93-2	M	26-35	L radius, distal third of diaphysis with healed oblique fracture. Slight posterior displacement of distal fragment. Anterior and posterior aspect of distal fragment with well remodelled callus. Distal articulation with contour change and marginal osteophytes. Ulnar articulation with eburnation
NU112	M	26-35	R tibia, middle third of diaphysis with healed fracture. Large (width=2.6 cm, length=8.5 cm) fusiform remodelled callus with almost smooth surface. No angulation or rotation but shortening by 0.5 cm
NU190	M	26-35	L tibia, middle third of diaphysis with healed fracture. Fusiform callus at medial aspect. No angulation or rotation
NU76	M	36-45	R tibia, posterior aspect of distal articular facet with healed fracture. Large remodelled callus with some remodelled pitting and remodelled sinuses; healed infection

NU47	M	45+	R humerus, proximal third of diaphysis with healed fracture. Large (2.6x4.0x1.2 cm) depressed area on medial aspect – superior end with post-mortem damage – cortex intact with small patches of woven pitted new bone formation
PL141	F	36-45	R clavicle, middle third of diaphysis with healed oblique fracture. Ca. 6.0 cm overlap, but no angulation
PL71	M	26-35	R femur, proximal epiphysis with healed fracture. Slight coxa vara with femoral head displaced in inferior direction and broadened neck. Remodelled new bone formation and sinuses on R tibia and fibula; osteomyelitis secondary to trauma?
PL131	M	26-35	L ulna, distal third of diaphysis with healed oblique fracture. Slight displacement of distal part in posterior direction. L tibia, distal third of diaphysis with healed fracture. Diaphysis enlarged with severe callus formation and osteomyelitic reaction. Callus bridge with L fibula. Ankylosis of tibia and talus
PL138	M	26-35	R ulna, distal third of diaphysis with healed oblique fracture. Slight posterior angulation of distal part
PL42	M	36-45	R clavicle, middle third of diaphysis with healed oblique fracture. Distal aspect slightly more angulated than L clavicle; shortened by 1.4 cm. Acromial articulation enlarged with osteophytes on facet and margin
PL76	M	36-45	R fibula, distal third of diaphysis with healed fracture. Medial aspect with remodelled pitted callus; lateral aspect smooth but raised. No angulation or rotation
PL116	M	36-45	R clavicle, middle third of diaphysis with oblique fracture. Non-union of fragments, but large irregular remodelled callus
PL79	M	45+	R clavicle, middle third of diaphysis with healed fracture. No angulation or shortening but remodelled callus on antero-posterior aspect. R radius, distal third of diaphysis with healed oblique fracture. Slight angulation of distal part in posterior direction
PL111	M	45+	L tibia, middle third of diaphysis with healed fracture. Medial aspect with exostosis (0.8x1.5 cm). Irregular remodelled callus, no pitting. L fibula, distal third of diaphysis with healed fracture Remodelled callus (2.0x4.0 cm) without pitting or angulation

Appendix C5, Table 1 Long bone fractures.

No.	Sex	Age	Description
AP41B	F	26-35	Unsided distal hand phalanx fused to head of intermediate phalanx; intermediate phalanx with pseudarthrosis at proximal end
AP44	F	26-35	L 11th and one L rib with healed fractures of body; slight angulation
AP88	F	26-35	L 2nd metacarpal, healed fracture of distal third of diaphysis; 45° angulation of distal diaphysis
AP120	F	26-35	15 ribs with horizontal fractures of bodies; three L, four R and four unsided ribs well healed. Two L and one R rib with pseudoarthrosis, R 12th rib with woven NBF at fracture line
AP137B	F	36-45	Unsided rib with healed fracture of body; slight depression on ventral, and remodelled callus on dorsal, aspects
AP126	M	26-35	Two R and four unsided ribs with well healed fractures of body
AP67	M	36-45	L 3rd metacarpal with healed fracture of middle diaphysis; fusiform callus. Slight angulation of distal part in inferior direction; 4.1 mm shorter than R 3rd metacarpal
AP12B	M	45+	R rib with fracture of tubercle; remodelled callus on dorsal aspect
CS13	F	16-25	R 4th metacarpal with healed fracture of middle diaphysis; slight bowing of distal part in inferior direction

CS15	F	36-45	L 11th rib with healed fracture at angle
CS7	F	45+	L rib with healed fracture at angle; remodelled callus on ventral aspect
CS21	M	26-35	T1 with fracture of spinous process; pseudoarthrosis
CS70	M	26-35	L 5th metacarpal with healed fracture of middle diaphysis; inferior angulation of distal part and slight lateral rotation. 3.4 mm shorter than R 5th metacarpal
CS33B	M	36-45	Unsided rib with healed fracture; remodelled callus and concavity on inferior margin
CS78	M	36-45	R mandibular corpus distal to R second incisor flat area of remodelled spiculated new bone formation with pointed horizontal exostosis on inferior margin, ends in sharp but remodelled tip. Broken off root of R 2nd premolar almost completely covered with calculus; 1st molar equally surrounded by heavy deposits. Maxillary second molar with calculus on occlusal surface and heavy deposits on buccal aspect. No signs of infection. R mandibular fossa with dense nodular NBF and eburnation secondary to fracture R mandible
CS159	M	36-45	R 5th metacarpal with healed oblique fracture of middle diaphysis; slight angulation and rotation of distal part in medial and inferior direction. 4.5 mm shorter than L 5th metacarpal
NT107	F	16-25	R 2nd rib with healed fracture of body
NT98	F	26-35	L 3rd rib with healed fracture; slight angulation
NT69	M	26-35	L mandibular ramus with spiculated remodelled NBF on anterior aspect running from the inferior aspect of the gonial angle almost to the alveolar crest of the L 3rd molar. Small area of spiculated remodelled NBF on the interior aspect of the gonial angle. Reduced width of L ramus (L=23.2mm, R=27.1mm) and reduced width of coracoid process (L=10.5mm, R=12.7mm – measurement taken at base of processes). The angle between the L coracoid process and the *processus condylaris* is more acute than the one on R side. The overall aspect of the mandible is asymmetrical with slight bulging anteriorly
NE133	F	26-35	R 2nd metatarsal of proximal diaphysis with remodelled callus on medial aspect (ca. 1.5 cm)
NE147	F	26-35	R and unsided rib with healed fracture of body
NE25	F	36-45	Two R ribs with oblique healed fractures at anterior part of corpus. Displacement of anterior fragment in inferior direction
NE81	F	36-45	Superior articular facets of 5th lumbar vertebra fractured; pseudoarthrosis
NE10	M	26-35	L mandibular body – lamina on internal aspect supero-lateral to mental spines (ca. 2.0 cm length) and small area of pitted remodelled new bone formation from infero-lateral to mental spines
NU12-1	M	45+	R 1st and 2nd rib with healed fractures at angle
NU173	M	45+	R 2nd and one R rib with healed fractures; two remodelled calluses on 2nd and three remodelled calluses on other rib
NU211	M	45+	R rib with healed fracture of body
PL13	F	26-35	R patella with healed partial fracture of lateral margin measuring 7.0x25.0 mm; lateral facet slightly skewed in posterior direction. Marginal osteophytes at medial facet
PL47	F	26-35	Unsided proximal hand phalanx with healed fracture at middle diaphysis
PL98	F	45+	L patella with very thin (2.0 mm) lateral facet and cortex with remodelled pitting and irregular surface; healed crush injury
PL71	M	26-35	R 3rd metatarsal with healed fracture of middle diaphysis; medial rotation of distal part. Remodelled pitting on remodelled callus

PL138	M	26-35	Unsided rib with healed fracture of body
PL104	M	36-45	L 1st proximal hand phalanx with healed fracture; distal articulation with eburnation, new bone formation and pitting. Proximal part rotated in medial direction
PL72	M	36-45	Unsided/unidentified metacarpal with healed fracture of middle diaphysis; slight superior bowing of distal part
PL116	M	36-45	Lateral margin of L scapular blade with remodelled callus (ca. 3 cm length). Healed fractures of L 2nd metacarpal (distal diaphysis), L 2nd metatarsal (middle diaphysis) and L 3rd metatarsal (distal diaphysis)
PL111	M	45+	L 1st proximal foot phalanx with healed fracture; inferior proximal aspect with slight depression and some remodelled pitting. Eburnation on distal articulation

Appendix C5, Table 2 Non-long bone fractures.

AS150	M	26-35	Central area of frontal bone, in alignment with sagittal suture, irregularly oval shallow depressed area (ca. 15.0x17.0 mm) with slightly raised remodelled margin; in centre of lesion ridge of lamellar bone (ca. 4.0x10.0 mm) Healed blunt force injury
CS17B	F	26-35	R parietal bone (parietal tuberosity) with circular depression (18.3 mm); very shallow, smooth walls, some pitting at centre, but diploë completely remodelled. No evidence of infection, inner table not affected Healed blunt force injury
NT55-1	M	36-45	L parietal bone with irregular shaped hole measuring ca. 2.5x3.0 cm. Smooth remodelled margins. Superior and slightly anterior to this perforation lies a depressed oval area measuring ca. 1.0x2.0 cm with some pitting Healed sharp and blunt force injuries
NE32	M	26-35	Two linear cuts on R frontal bone almost parallel to each other and perpendicular to coronal suture, both ca. 4 cm length. Both cuts slightly polished, no remodelling Unhealed sharp force injuries
NE141-1	M	26-35	L parietal bone with four linear cuts: 1) L posterior parietal fragment with cut (55.3 mm length), internal table, diploë and external table with clean almost straight cut rectangular to sagittal suture. Slightly bevelling from posterior to anterior aspect 2) anterior aspect of L parietal fragment with cut on anterior edge (36.5 mm) 3) same aspect as 2) but not quite parallel (35.2 mm) 4) on posterior aspect of L parietal bone cut of 78.9 mm length; convex bowing of cut No remodelling; all cuts slightly polished and with scratch marks Four unhealed sharp force injuries
NE78-2	M	36-45	Linear cut on L parietal bone; ca. 12 cm length from postero-superior to antero-inferior aspect. No remodelling Unhealed sharp force injury
NE118	M	45+	Shallow depressed area on middle aspect of L parietal bone reaching sagittal suture (length: 4.7; width: 19.5 mm). Margins remodelled but internal table eroded Healed blunt force injury
NU209	F	26-35	Two linear cuts on R parietal bone: 1) straight cut from mid-sagittal suture to posterior aspect

			ending 1.6 cm short of lambdoid suture (length: 7.7 cm). Edge only slightly bevelled in lateral direction. Clean cut through outer table and diploë, margin of internal table irregular and rugged 2) linear cut on lateral aspect; almost straight and running parallel to squamous suture (length: 4 cm) cutting cleanly through external table, but diploë and internal table rugged; slight lateral bevelling Unhealed sharp force injuries
NU92	F	36-45	L posterior parietal bone with elliptical shallow depression (2.0x4.8 cm) adjacent to sagittal suture Healed blunt force injury
NU213-1	F	36-45	Oval depressed area (1.6x2.0 cm) on R superior frontal bone with posterior margin reaching coronal suture; very shallow with irregular pitted surface. Healed blunt force injury
NU169	M	16-25	Linear cut on both anterior parietal bones with depressed line running from L aspect of sagittal suture to R coronal suture (length=5.2 cm, width=5.7 mm, depth=5 mm). Two post-mortem perforations on L and R parietal bones. No pitting. Margins of linear cut completely remodelled. Isolated elliptical bone fragment caused by extraction of weapon. Healed sharp force injury
NU1209	M	26-35	L frontal bone with circular shallow depressed area (11.0 mm) at frontal tuberosity; internal frontal normal and no pitting. Healed blunt force injury
NU208-1	M	26-35	Linear cut on L frontal bone (6.2x36.0x3.6 mm) with edges remodelled, slight pitting on sloping walls. Internally small perforation (2.0 mm), possibly post-mortem damage. Healed sharp force injury
NU220	M	26-35	Linear cut on L frontal bone – elongated depression with remodelled sloping margins and walls – 1.2x3.0 cm externally, internally irregular circular new bone formation of 1.3 cm. No pitting. Healed sharp force injury
NU75	M	36-45	L anterior parietal bone with shallow depressed lesion (3.8x6.0 mm) – gently sloping remodelled walls, pinprick sized pitting but cranium with general pitting. Healed blunt force injury
NU99	M	36-45	R parietal bone, lateral aspect with long (5.8 cm) linear cut running from supero-posterior (parietal tuberosity) to infero-anterior aspect, ending shortly (1.6 cm) before coronal suture. Margins completely remodelled. Original cut slightly sinuous with irregular anterior aspect, but post-mortem damage. Interior parietal bone unaffected. Healed sharp force injury
NU211	M	45+	Linear cut on L parietal bone. Medial aspect with cut running from mid-sagittal to squamous suture ending ca. 4 cm superior to temporal bone. Smooth and bevelled (supero-posterior to infero-anterior bevelling) crescent-shaped cut of ca. 8 cm length; no remodelling. Unhealed sharp force injury
PL12	M	26-35	L parietal bone with shallow depressed area at parietal tuberosity; circular (1.47 cm). No reactive new bone formation or pitting, internal skull not observable. Healed blunt force injury
PL27	M	36-45	R parietal bone with circular depression (2.1 cm) 1.2 cm superior to squamous suture. No reactive new bone formation or pitting, internal table normal. Healed blunt force injury
PL82	M	36-45	L posterior parietal/occipital bones; oval depression (3.2x4.2

	F		cm) – no reactive new bone formation or pitting; inner table normal. Healed blunt force injury
PL120	M	45+	Linear cut at R frontal bone – superior orbital margin medial/middle aspect with vertical cut; completely remodelled margins (26.6 mm length) ending shortly superior to supraorbital notch. Healed sharp force injury

Appendix C5, Table 3 Individuals with cranial injuries.

No.	Sex	Age	Description
AP50	F	16-25	L5 with separation between superior and inferior facets
AP108	F	16-25	L5 with separation between superior and inferior facets (Lumbarisation and spina bifida occulta)
AP18	F	26-35	L5 with separation between superior and inferior facets
AP120	F	26-35	L5 with separation between superior and inferior facets
AP48	F	36-45	L5 with separation between superior and inferior facets Spondylolisthesis: anterior aspect of sacral base rounded with osteophyte formation
AP151	F	36-45	L5 with separation between superior and inferior facets Spondylolisthesis: base of sacrum with osteophytes on anterior margin
CS155	F	26-35	L2 with separation between superior and inferior facets
CS167B	F	26-35	L4 with separation between superior and inferior facets
CS8	F	36-45	L2 with separation between superior and inferior facets
CS10	F	36-45	L5 with separation between superior and inferior facets
CS23	F	36-45	L5 with separation between superior and inferior facets Spondylolisthesis: osteophytes on lateral inferior body of L5 and lateral to sacral base, sacral base with irregular surface (Spina bifida occulta)
CS160	F	36-45	L5 with separation between superior and inferior facets
CS26	F	45+	Fissure inferior to R superior facet of L5; partial spondylolysis
CS103	M	26-35	L4 and L6 with separation between superior and inferior facets (Lumbarisation)
CS33B	M	36-45	L5 with separation of L inferior facet; partial spondylolysis (Spina bifida occulta)
CS93	M	36-45	L5 with separation between superior and inferior facets Spondylolisthesis: osteophytes on anterior margin of vertebral body and sacral base
NT58	M	16-25	L5 with separation between superior and inferior facets
NT69	M	26-35	T12 with separation between R superior and inferior facets; partial spondylolysis L1 with separation between R superior and inferior facets; partial spondylolysis (Sacralisation)
NE44	M	26-35	T12 with separation between R superior and inferior facets; partial spondylolysis (Lumbarisation)
NE74	M	26-35	L4 with separation between R superior and inferior facets; partial spondylolysis L5 with separation between superior and inferior facets
NE143	F	26-35	L4 with separation between superior and inferior facets
NE147	F	26-35	L4 and L5 with separation between superior and inferior facets
NE22-1	F	36-45	L3 with separation between superior and inferior facets (Sacrum not observable)
NU209	F	45+	L5 with separation between superior and inferior facets

NU3-1	F	36-45	L5 with separation between superior and inferior facets Spondylolisthesis: L5 and sacral base with osteophytes on anterior margin (Spina bifida occulta)
NU169	M	45+	L4 and L5 with separation between superior and inferior facets Sacrum not observable
NU211	M	36-45	L4 with separation between superior and inferior facets (Sacrum not observable)
PL16A	F	16-25	L4 with separation between superior and inferior facets
PL45	F	26-35	L4 and L5 with separation between superior and inferior facets
PL99	F	36-45	L5 with separation between R superior and inferior facets; partial spondylolysis (Sacrum not observable)
PL102	M	26-35	L5 with separation between superior and inferior facets
PL116	M	36-45	L5 with separation between superior and inferior facets (Sacrum not observable)

Appendix C5, Table 4 Individuals with spondylolysis and spondylolisthesis.

APPENDIX C6 NON-SPECIFIC INFECTIONS

No.	Sex	Age	Description
AP120	F	26-35	R temporal bone with abscess (irregular circular ca. 1.5 cm) posterior to external auditory meatus; sharp but remodelled margin, walls with spiculated remodelled NBF
AP115B	F	26-35	Remodelled striated NBF on both medial aspects of middle third of tibial diaphyses
AP162	F	26-35	Both distal tibiae and fibulae with coarse lamellar bone on distal third of diaphysis (tibiae – lateral; fibulae – medial aspect)
AP171	F	36-45	L tibia with grey- coloured shell of 'soap bubble'-like NBF on posterior aspect of proximal diaphysis (2.0x5.7 cm; height=1.1 cm). Distal third with same NBF but more extensive (10.0 cm superior to distal facet) surrounding distal end of bone. Surface of shell structure nodular and compact, but disorganized; interior structure is porous trabecular bone. Near medullary cavity 'fluff'-like appearance. Distal articular facet destroyed and L talar bone not preserved. L fibula with grey-coloured NBF – lamellar on entire diaphysis – anterior margin, extending to medial aspect and posterior margin on distal third; here more 'soap bubble'-like NBF Distal end covered with 'soap bubble'-shaped NBF. Some form of organization on lateral aspect of distal end – villiferously-shaped NBF growing from antero-distal to postero-proximal
AP56	M	16-25	L tibia – proximal third – medial aspect with mixed NBF – woven pitted and lamellar striated patches of ca. 4.0 cm length and ca. 2.0 cm width
AP68	M	26-35	Both medial aspects of tibiae with remodelled striated NBF
AP123	M	26-35	Remodelled striated NBF on middle and distal third of L and entire diaphysis of R lateral tibiae and on middle and distal third of both medial fibulae
AP150	M	26-35	Proximal R tibia – medial aspect with three distinctive irregular oval areas of lamellar striated NBF (3.5x10.0 mm; 2.5x10.0 mm; 1.8x4.5 mm)
AP152	M	26-35	Internal skull (frontal and both parietal bones with off-white areas of vessel impressions). Thoracic vertebrae T9 and 10 with woven pitted NBF on right antero-lateral aspect of body. All long bones with thickened diaphyses, except humeral diaphyses normal, but grey woven pitted NBF on posterior distal diaphyses and epiphyses. L fibula with post-mortem break of distal diaphysis showing three concentric layers of NBF. Both femora with remodelled lamellar bone (striated, 'flame-like'). On both ilia – posterior aspect, superior to acetabulum remodelled striated NBF. Both clavicles with grey woven and pitted NBF on acromial ends (superior aspect) and on medial aspect of diaphysis (superior). Woven pitted NBF on both exterior mandibular rami. All ribs of R side, but not L ribs. Metacarpals, proximal and intermediate hand phalanges with woven pitted NBF, Metacarpal shafts thickened. Metatarsals and proximal foot phalanges with woven pitted NBF; Metatarsal shafts thickened and both 4th and 5th metatarsals bowed laterally
AP31	M	45+	Both lateral fibulae (proximal and middle third) with striated

			remodelled NBF; R side additionally on posterior aspect proximal and middle third
AP99B	M	45+	L tibia woven pitted and striated NBF on posterior aspect of distal epiphysis (1.8x3.2 cm) R tibia woven pitted NBF on posterior aspect of distal third of diaphysis (2.3x2.9 cm)

Appendix C6, Table 1 Apple Down. Individuals with non-specific infection.

No.	Sex	Age	Description
CS167B	F	26-35	R distal third of fibula with well-healed fracture resulting in slight thickening of diaphysis (L=14.2 mm, R=17.2 mm) with remodelled porous and striated NBF on medial aspect
CS115	F	45+	Healed spiral fracture of L radius midshaft with shortening (L=23.7 cm, R=25.7 cm) and medial displacement of distal part. Circular sinus on distal lateral margin of L radius (3.6 mm) surrounded by small patch of finely pitted NBF
CS128	F	45+	L fibula – proximal third of diaphysis, medial aspect with patch of striated remodelled NBF (0.5x2.0 mm). L tibia – middle third of diaphysis, medial aspect with striated remodelled NBF (ca. 2.0x5.0 cm)
CS132	F	45+	R tibia – proximal third, lateral to tibial tuberosity with remodelled pitted and striated NBF (ca. 1.6 cm)
CS137	F	45+	L proximal third of tibia – medial margin inferior to tibial tuberosity with small area of striated remodelled NBF (ca. 1.5 cm)
CS38	M	36-45	L tibia – middle third of diaphysis – anterior margin thickened slightly on medial aspect (length ca. 4.0 cm; antero-posterior diameter: L=3.3 cm, R=3.2 cm). Remodelled striated NBF on medial aspect of middle third of diaphysis. On posterior aspect opposite thickening small depression with three pin-prick sized remodelled circular perforations
CS126	M	16-25	R tibia – middle third of diaphysis – medial aspect with pitted and striated remodelled NBF – height ca. 5.0 cm, width ca. 2.4 cm
CS50	M	26-35	R 2nd metatarsal with irregular dense remodelled NBF on supero-medial aspect of diaphysis (2.7 cm length, 3.7 mm width); two small patches on lateral side; smaller (14.6x3.4 mm) on L 4th metatarsal infero-lateral aspect
CS72	M	26-35	L femur – proximal and middle third of diaphysis – medial and posterior aspect with pitted remodelled NBF. L tibia – medial aspect of entire diaphysis with striated remodelled NBF
CS127	M	26-35	R fibula – middle third of diaphysis – lateral aspect with spiculated remodelled NBF (0.8x4.0 cm)
CS93	M	36-45	L ulna with healed midshaft fracture – remodelled fusiform callus (2.7 cm length). No angulation or rotation but signs of infection: porous woven NBF on anterior and lateral aspects of proximal and middle third of diaphysis extending from anterior margin of inferior trochlear facet to callus on anterior aspect. Medial aspect with little porous woven NBF on middle aspect of diaphysis
CS180	M	36-45	R tibia – proximal third – medial aspect with irregular oval area of remodelled dense NBF (1.5x3.5 cm), inferiorly small patch of remodelled striated NBF. On posterior aspect – same height as striated NBF – oval dense remodelled NBF (3.5x9.0 mm)
CS6	M	45+	L and R tibial diaphyses with remodelled striated NBF on entire medial aspect and proximal-middle third lateral aspect
CS63	M	45+	Medial aspects of both tibiae with remodelled striated NBF, R medial middle third of diaphysis with oval dense NBF (3.0x4.2 cm). L tibia – lateral aspect with alternating areas of pitted NBF

			and remodelled striated NBF. R fibula – lateral aspect with patches of remodelled striated NBF on middle third of diaphysis
CS100	M	45+	R tibia – proximal third, medial aspect with remodelled striated NBF (ca. 5.0 cm length, 2.5 cm width) and two small irregular osteophytes
CS150	M	adult	L tibia – proximal third of diaphysis, medial aspect with remodelled, striated NBF. Anterior aspect of middle third of L femoral diaphysis oval raised area slightly elevating from medial to lateral side (1.4x2.5 cm). Lateral aspect sharply demarcated, dense remodelled bone

Appendix C6, Table 2 Castledyke South. Individuals with non-specific infection.

No.	Sex	Age	Description
NT60	M	16-25	R femur patches of NBF prox. and middle third medial side mixed woven (greyish colour and porous) and lamellar (striated NBF) – elevated onion skin-like layering measuring 2.7-7.5 mm
NT69	M	26-35	Ankylosis between L calcaneus and talus (post-mortem damage of trochlea, head and posterior calcaneus) – fusion on antero-medial aspect of articular facet. L navicular slightly reduced width (3.6 cm) compared to R side (3.8 cm). L mandibular ramus with spiculated remodelled NBF on anterior aspect running from inferior aspect of gonial angle almost to alveolar crest of L 3rd molar. Small area of spiculated remodelled NBF on interior aspect of gonial angle. Reduced width of L ramus (L=2.3 cm, R=2.7 cm) and reduced width of coracoid process (L=1.1 cm, R=1.3 cm – measurement taken at base of processes). The angle between the L coracoid process and the condylar process is more acute than on R side. Overall, aspect of mandible is asymmetrical
NT78	M	45+	L distal third of tibia, lateral aspect with lamellar and pitted NBF (5.0 cm). Ankylosis of distal tibia and fibula – remodelled callus with pitted appearance and two sinuses on the inferior aspect of the callus (diameter=5.0 mm and 3.0 mm, respectively). There is no sign of a healed fracture (no angulation), although this may be a case of chronic osteomyelitis secondary to a well-healed injury. It was not possible to x-ray the bones, since they are part of an exhibition at Preston Hall/Stockton. D. Birkett described this as a bony fusion at the ankle joint most likely caused by bleeding following a tear of the ligament which joins the two bones, resulting from a fall or a twisted ankle. He did not find any evidence of a fracture (Marlow and Birkett, 1990)
NT112	N/D	16-25	L femur – medial condyle woven, porous NBF and lytic lesion (1.3 x 1.9 mm)

Appendix C6, Table 3 Norton. Individuals with non-specific infection.

No.	Sex	Age	Description
NE16	F	26-35	R auricular surface with oval area of osteoclastic and osteoblastic reaction (7.8x9.8 cm) – irregular depressions with sclerotic margins
NE124	F	26-35	L tibia with striated lamellar NBF on middle third of diaphysis on lateral aspect and horizontal impression of blood vessel
NE133	F	26-35	Medial aspect of both tibial diaphyses with remodelled pitted NBF and thickening of distal third of R tibia (ca. 3.0 cm) on lateral aspect
NE141-4	F	26-36	R distal tibia – articulation with fibula with patch of woven

			pitted NBF
NE141-5	F	26-35	L mandibular ramus – alveolar process of 1st-3rd molars with patches of woven pitted NBF – 1st molar on anterior aspect, 2nd and 3rd molars superior aspect of alveolar process
NE143	F	26-35	Both proximal and middle thirds of tibial diaphysis – lateral aspect with remodelled striated NBF
NE147	F	26-35	Both femora with remodelled striated NBF on entire diaphyses
NE75	F	36-45	Slight pitting on both tibiae – middle third of diaphysis – lateral aspect. Anterior nasal spine reduced to small round protuberance, inferior border of nasal aperture rounded; Both 1st maxillary incisors and L 2nd incisor lost antemortem
NE78-1	F	36-45	R clavicle – sternal end – inferior aspect with remodelled striated NBF; on proximal third of diaphysis – inferior aspect small area (ca. 5.0x8.0 mm) with woven, pitted NBF. Manubrium with remodelled spiculated and partially porous NBF on anterior and posterior surface. Base of sacrum with large lytic lesion with remodelled but irregular walls ca. 4.0 mm deep – only R side of sacral base present. L talus – facet with posterior calcaneus – anterior aspect with lytic lesions – remodelled, rounded margins with large porous lesions on walls (6.1x10.8x2.0 mm and 3.0x3.4 mm)
NE66	F	45+	L mandibular body, below sockets of 1st and 2nd molars woven, pitted and plaque-like NBF. At 1st molar 3.0x3.5 mm; at 2nd molar 2.0x3.0 mm. Both tibiae diaphyses and R fibula diaphysis with remodelled striated NBF
NE81	F	45+	L tibia with lamellar, spiculated NBF (1.0x2.0 cm) on medial aspect of tibial tuberosity. Both sacroiliac joints with ankylosis
NE50-2	F	adult	R tibia, entire diaphysis, thickened with lamellar, striated NBF. Sinus (1.2 cm) with remodelled margins on anterior distal aspect
NE134	M	16-25	R 2nd metatarsal with finely pitted lamellar NBF on middle and distal third of diaphysis – onion skin-like layering
NE10	M	26-35	Possible fracture of L mandibular body – laminar piece of bone on internal aspect supero-lateral to mental spines (ca. 2.0 cm length) and small area of pitted remodelled NBF infero-lateral to mental spines
NE50-1	M	26-35	R fibula, distal third of diaphysis, medullary cavity almost obliterated with porous NBF (visible due to post-mortem damage)
NE51	M	26-35	R tibia – medial side of diaphysis; R fibula – lateral side of proximal third of diaphysis with lamellar, striated NBF. Size – tibia: ca. 4.0x20 cm; fibula: ca. 1.0x6.0 cm
NE122-1	M	26-35	R femur – posterior aspect middle and distal thirds of diaphysis with plaque-like patches of woven striated NBF on lateral aspect
NE61-1	M	36-45	R tibia – oblique fracture of distal third of diaphysis; ca. 4.5 cm overlap; angulation ca. 5° posterior; 100 per cent apposition; ca. 8.0 cm superior to distal fragment callus bridge with large sinus with smooth margins on anterior aspect (0.5x1.2 cm); on posterior aspect callus bridging almost smooth on superior part, but three irregular shaped perforations on inferior part Remodelled striated and pitted NBF indicative of healed infection Both tali – heads, lateral surface and posterior articulation with calcaneus with marginal lipping – more severe on R side; posterior articulation with calcaneus with lytic lesion on anterior aspect (3.0x6.0 mm); R talus small circular area with woven

			porous NBF (ca. 5.0 mm) – lateral to lytic lesion
NE80	M	36-45	Sacrum – S4 and S5 – anterior aspect with three remodelled lytic lesions (ca. 1.5 cm). Palate – inferior aspect with irregular pitting but no NBF. R distal third of fibula – medial aspect with dense, remodelled, slightly spiculated NBF (1.5x2.5 cm) – anterior margin thickened
NE84	M	36-45	L fibula – middle third of lateral diaphysis with slightly thickened and highly pitted area of lamellar bone (ca. 1.0x3.5 cm). R ilium with irregular osteophytes superior to auricular surface; acetabulum with large subchondral cysts, destruction of lunate surface and marginal lipping. Superior to acetabulum large, nodular osteophytes, highly pitted. Medial to acetabulum extension of dense remodelled bone, but additionally some small patches of grey woven and finely pitted NBF. Posterior and inferior aspect of R femoral neck with small areas of woven pitted NBF
NE126-1	M	36-45	Both middle thirds of tibiae with remodelled striated NBF on lateral aspect
NE15	M	45+	L clavicle, lateral superior and posterior aspect, woven, pitted, superior aspect 5.0x9.0 mm - slightly raised area with NBF surrounded by pitted cortex; posterior aspect: 3.0x9.0 mm
NE39	M	45+	Both tibiae, proximal and middle third of diaphyses – medial side, lamellar, some pitting, striated NBF
NE79	M	45+	Both tibiae, proximal third of R lateral diaphysis and L medial side, mostly lamellar and striated, but small area of pitted woven NBF
NE102	M	45+	L tibia – distal third of diaphysis/distal epiphysis with patches of woven, highly pitted NBF
NE120	M	45+	R fibula – proximal third of diaphysis with remodelled lamellar striated NBF on medial aspect
NE140-2	M	adult	Middle third of L tibia diaphysis thickened on anterior and lateral aspect – greatest dimensions on middle of thickened area (ca. 13.0 cm – woven and lamellar bone with some pitting). On distal third of L tibia lamellar striated and plaque-like NBF on lateral aspect. L fibula – middle third of diaphysis with irregular lamellar NBF with some pitting on all aspects – irregular surface of diaphysis
NE121	N/D	adult	L lateral aspect of tibia – lamellar striated NBF especially on distal third of diaphysis
NE33	SA	2-4	Woven, pitted NBF superior to R external auditory meatus (4.3x7.2 mm)
NE132-1	SA	2-4	Pitting of both palatine bones
NE1-1	SA	6-8	R clavicle, lateral third of diaphysis, posterior aspect, woven and lamellar (mixed NBF), 18.6 mm, L side not affected
NE17	SA	6-8	L femur, posterior middle-distal third, woven, slightly pitted NBF, size=1.0x5.0 cm; 0.6x3.5 cm

Appendix C6, Table 4 Neresheim. Individuals with non-specific infection.

No.	Sex	Age	Description
NU102	F	16-25	L tibia – middle/distal third of diaphysis – lateral aspect with slightly raised oval thickening – continuous cortex slightly pitted and striated but remodelled (1.5x3.5 cm)
NU146	F	26-35	L temporal with remodelled perforation superior to external auditory meatus – smooth rounded walls (2.4 mm) surrounded by some fine remodelled pitting. R temporal with slight depression at

			same location – circular area ca. 8.3 mm covered with some remodelled pitting (ca. 0.5 mm)
NU166	F	26-35	L tibia – middle third of diaphysis, lateral aspect with layer of woven pitted and striated NBF
NU209	F	26-35	Both tibiae with woven pitted and remodelled striated NBF on middle and distal third of diaphysis medial aspect and distal third lateral aspect. Both fibulae with pitted and striated mixed NBF of middle and distal third of diaphyses medial aspects
NU8-1	F	36-45	Woven pitted NBF on proximal and middle third of R femur – posterior aspect, lateral to linea aspera thin band of NBF (width 3.7 mm). Woven pitted and striated NBF on R tibia – proximal and middle third of diaphysis – lateral aspect (10.8x11.5 cm) Middle/distal third – medial aspect with woven pitted and striated NBF (1.5x5.5 cm); distal third – medial aspect with woven pitted NBF (2.2x5.0 cm)
NU61	F	36-45	R tibia – distal third of diaphysis – medial aspect with woven pitted and striated NBF (1.1x4.2 cm) and on lateral aspect – distal third (0.6x1.8 cm)
NU135	F	36-45	R femur and tibia – entire diaphysis with striated remodelled NBF
NU6	F	45+	R tibia – middle third of diaphysis – lateral aspect with oval thickening (8.2x21.5 mm), slightly raised area of remodelled striated bone
NU31	F	45+	Both palatine bones highly pitted – mixed pitted and striated NBF
NU210	F	45+	R proximal tibia with woven pitted NBF on posterior and lateral aspects
NU82	M	16-25	L maxilla – distal aspect of remodelled socket of 3rd molar with small patch of woven pitted NBF
NU110	M	16-25	L fibula – posterior aspect – proximal/middle third – woven pitted and striated NBF (0.7x1.4 cm) and middle third – woven pitted and striated (0.7x.7 cm). R tibia – middle/distal third of diaphysis – medial aspect with woven pitted and striated NBF (1.2x4.3 cm)
NU139	M	16-25	Woven pitted NBF with few larger pits at R distal radius – ulnar aspect and few patches on medial aspect of middle third of diaphysis. L proximal ulna – small area of NBF on anterior aspect. R ulna – entire diaphysis covered by thick layer (1.7 mm) of NBF; layer loosely attached to cortex. Both femora – proximal and middle third of diaphysis – posterior aspect with pitted and striated mixed NBF. Both tibiae – entire diaphysis covered with thin layer of woven NBF (0.5 mm) – layer loosely attached to cortex. Both fibulae with mixed NBF – patches covering anterior and medial aspect. Both calcanei with NBF at lateral aspect of body – thick layer. L pelvis with thin patch of pitted NBF on lateral aspect superior to obturator foramen. R pelvis with thin patch at posterior aspect – superior to inferior, lateral
NU93-1	M	26-35	L tibia – medial aspect, middle and distal third with remodelled striated NBF. L fibula – middle third, anterior aspect with remodelled spiculated NBF (0.6x7.6 cm); proximal diaphysis flattened in medio-lateral direction (L=6.0 mm, R=10.2 mm). R fibula – middle/distal third, medial aspect with woven pitted and striated NBF (1.0x5.5 cm but post-mortem damage on distal extension)
NU112	M	26-35	L femur – distal third, posterior aspect with elongated raised NBF (2.3x6.5 cm) cortex expansion with relatively smooth surface but some areas of porous pitting (woven NBF). L 1st metacarpal with expansion of head, although no NBF; proximal end with woven

			pitted NBF on posterior aspect extending from ca. middle third to proximal end. R 1st metacarpal with expansion of head showing slight marginal lipping, severely expanded diaphysis and proximal articulation – blown-up, swollen appearance; marginal lipping on proximal facet. Length R=39.9 mm, L=48.8 mm
NU120	M	26-35	L external mandibular body with excessive woven porous NBF extending from 1st premolar to 2nd molar concentrated around mental foramen but not infiltrating it
NU156	M	26-35	L tibia and fibula – middle third of diaphysis, lateral aspect with lamellar striated NBF
NU7	M	36-45	Both tibiae with striated remodelled NBF on lateral aspects of middle and distal diaphyses
NU76	M	36-45	L tibia with remodelled striated NBF on distal and middle aspect of diaphysis – lateral side. Interior aspect of R mandibular angle with woven pitted NBF extending from superior aspect of mylohyoid foramen to inferior, to socket of 3rd molar
NU99-1	M	36-45	L proximal ulna with expanded diaphysis – tapering at distal aspect, proximal post-mortem damage. Medullary cavity obliterated by trabecular bone. L posterior ilium with several patches of woven pitted NBF superior to acetabulum and sciatic notch. R with more extended pitted and striated NBF surrounding middle and superior aspect of acetabulum. L femur with woven pitted NBF on proximal posterior aspect – medial and inferior to lesser trochanter and on medial aspect of middle third of diaphysis – focal concentration. R femur with post-mortem damage at posterior aspect of neck but remains of woven pitted NBF visible anterior to lesser trochanter. Distal third with numerous patches of woven pitted NBF – medial, lateral and posterior aspects. R tibia with woven pitted and striated NBF mostly on proximal and middle third, lateral aspect and distal third anterior aspect – but probably more excessive with loss of only loosely attached thick layers (1.4 mm). L tibia with excessive pitted and striated NBF on proximal and middle third – lateral aspect and proximal and distal third of diaphysis – posterior aspect. L tibia – middle third, medial aspect with area of raised oval cortex (4.4x12.9 mm). L fibula with focal areas of woven pitted NBF middle third – posterior aspect and distal third – lateral and posterior aspect. R fibula with focal patches of woven pitted and striated NBF on anterior and medial middle third as well as distal third of diaphysis
NU109	M	36-45	L maxilla – lateral buccal aspect with woven pitted NBF covering some nodular remodelled and pitted NBF situated ca. 2.5 cm superior to alveolar crest on external aspect of L maxillary sinus
NU180	M	36-45	R tibia – middle third of diaphysis, lateral aspect with remodelled striated NBF at two localized area (1.2x2.0 cm)
NU185	M	36-45	R tibia – middle third of diaphysis, lateral aspect with lamellar pitted NBF (1.4x3.5 cm)
NU190	M	36-45	L calcaneal heel – superior aspect with large lytic lesion – irregularly shaped (ca. 2.0 cm) with rounded remodelled margin and spiculated pitted interior. Several small remodelled holes
NU201	M	36-45	L lateral tibia – proximal and middle third with remodelled striated and slightly pitted NBF
NU212	M	36-45	L medial tibia with remodelled striated NBF on middle third
NU241	M	36-45	L tibia with remodelled pitted and striated NBF on proximal and middle third of lateral diaphysis
NU12-1	M	45+	R tibia – proximal third of diaphysis, lateral aspect with mixed

			pitted and striated NBF (1.3x3.5 cm); proximal/middle third of diaphysis – lateral aspect with remodelled striated NBF (1.2x2.5 cm)
NU47	M	45+	R proximal humerus with large (2.6x4.0x1.2 cm) depression on medial aspect – superior end with post-mortem damage – cortex intact with small patches of woven pitted NBF
NU173	M	45+	Woven pitted NBF on maxilla – both sides on molar area and superior to L canine to 2nd premolar area. Circular shallow depressed area (5.2 mm) on L parietal – ca. 1.5 cm lateral to sagittal suture and ca. 2.5 cm posterior to coronal suture – fine remodelled pitting of ca. 4.0 cm radius. Both medial middle thirds of tibial diaphyses remodelled with striated and pitted NBF. On R middle/distal third circular area of lamellar NBF (5.3 mm). Both middle thirds of tibial diaphyses – R side lateral aspect with obliquely running band (from antero-superior to postero-inferior) of remodelled pitted NBF (1.5x2.5 cm). L more circular area (ca. 2.0 cm) with remodelled striated NBF overlaid by woven pitted NBF
NU57	M	adult	R tibia – proximal and middle third of diaphysis, lateral aspect with mixed (pitted and striated) NBF (1.3x6.5 cm and 1.0x3.7 cm)
NU144-1	M	adult	R humerus – proximal/middle third of diaphysis, posterior aspect with small patch of woven pitted NBF. Woven pitted NBF on L radius, superior and posterior to ulnar tuberosity, anterior and posterior aspect of middle third of diaphysis, distally anterior and medial aspect. L femur with excessive woven pitted and striated NBF on medial and lateral aspect covering proximal/middle, middle and middle/distal third. R tibia – entire diaphysis, lateral and posterior aspect with striated lamellar NBF. Middle/distal third of diaphysis with woven pitted and striated NBF on medial aspect – L fibula with possible callus formation on proximal diaphysis (post-mortem damage) and sinus (2.6 mm) on posterior aspect. Medullary cavity almost filled by trabecular bone, cortex with porous appearance. L and R fibulae with lamellar striated and nodular NBF on medial aspect entire diaphysis, lateral aspect – entire diaphysis with woven pitted and striated NBF. Both calcanei – lateral aspects of body with woven pitted NBF
NU22-1	N/D	16-25	Woven pitted NBF on external posterior parietals, middle and inferior occipital, temporal bones with mastoid process and mandible (external gonial angles)
NU4-3	N/D	adult	R tibia – medial aspect middle third of diaphysis with striated remodelled NBF ca. 12.0 cm length
NU35-2	N/D	adult	Both palatine bones highly pitted
NU202	SA	14-16	Both maxillae – buccal superior aspect of 3rd molars with fine remodelled pitting

Appendix C6, Table 5 Nusplingen. Individuals with non-specific infection.

No.	Sex	Age	Description
PL75A	F	16-25	L tibia – proximal and middle third – lateral aspect with striated remodelled NBF; middle/distal third – medial aspect striated remodelled NBF; distal third medial aspect woven pitted NBF (2.5 cm)
PL77	F	16-25	Both distal tibiae – lateral aspect with pitted and striated/woven NBF (2.5x3.5 cm). L tibia middle/distal third – medial aspect with pitted and striated woven NBF (1.8x7.1 cm). L fibula – distal third, medial aspect with pitted and striated woven NBF (0.9x6.5

			cm)
PL98	F	45+	L tibia – middle third of diaphysis with fine remodelled pitting on medial aspect
PL110	F	adult	Osteomyelitis/TB? – trabecular structure of both ilia and sacrum very coarse and disorganized. Sacrum additionally with finely grained trabeculae and possible oval lytic lesion on anterior aspect between S1/2 (1.3x3.0 cm); one lumbar body with coarse trabecular structure
PL71	M	26-35	L fibula with lamellar striated/pitted NBF on proximal third lateral aspect (1.5x6.0 cm). R tibia and fibula with irregular enlargement of diaphyses – candle wax-like NBF and several lytic lesions
PL131	M	26-35	L distal tibia with healed fracture. Diaphysis grossly enlarged with severe callus formation and sinus. Callus bridging L fibula. Ankylosis of talus.
PL138	M	26-35	R distal ulna with healed fracture; distal third only fragmentary preserved but angulation in postero-lateral direction visible R distal ulna with osteomyelitis – sinus (6.5 mm) on antero-medial aspect and small exostoses. R 1st metatarsal with remodelled NBF on medial aspect of middle diaphysis (3.8 mm)
PL72	M	36-45	1st L metatarsal head destroyed – pitted remodelled osteophytes, distal aspect enlarged, medial aspect with cystic lesions. Exostosis on superior lateral aspect
PL91	M	36-45	L tibia – proximal third – lateral aspect with remodelled striated NBF. L fibula – whole diaphysis – lateral aspect with remodelled striated NBF
PL111	M	45+	Proximal foot phalanx with remodelled callus formation at superior aspect of diaphysis. Inferior proximal aspect with slight depression and some remodelled pitting
PL120	M	45+	L fibula – middle third of diaphysis with remodelled NBF(0.5x2.0 cm)
PL10	M	adult	Both medial tibiae – proximal and middle third of diaphyses with remodelled striated NBF (ca. 2.5x12.0 cm). Both lateral fibulae – proximal third with remodelled striated NBF (0.8x8.0 cm)
PL87	M	adult	Both tibiae and R fibula with thickened diaphyses but cortex very irregularly eroded
PL54	SA	10-12	L maxilla – superior to sockets of canine to 2nd molar remodelled pitted NBF – irregular patch (1.4x2.3 cm). R maxilla – superior to sockets 1st to 3rd molars woven pitted NBF (2.2x3.0 cm)

Appendix C6, Table 6 Pleidelsheim. Individuals with non-specific infection.

No.	Sex	Age	Description
AP44	F	26-35	R antrum with spiculated not remodelled NBF
AP88	F	26-35	Both antra with remodelled spiculated NBF
AP48	F	36-45	Both antra with remodelled spiculated NBF
AP55	F	36-45	L antrum with spiculated remodelled NBF
AP105	F	36-45	Woven pitted NBF on roof of R maxillary sinus (rest of sinus not preserved)
AP107	F	36-45	R sinus wall covered with patches of remodelled spiculated NBF
AP151	F	36-45	R antrum with remodelled spiculated NBF around perforation (not from roots – lies posterior to 3rd molar)
AP157	F	36-45	Remodelled spiculated NBF on L antrum around root perforations; patch of NBF on L wall
AP78	F	45+	R antrum with remodelled spiculated NBF
AP39	M	26-35	R sinus with small patches of spiculated NBF on wall and antrum

AP118	M	26-35	R sinus wall with remodelled spiculated NBF
AP125	M	36-45	R antrum with pitting around perforation of M2 root
AP138A	M	36-45	L antrum and wall covered with plaque-like NBF remodelled; spiculated and pitted – R side only wall preserved – equally affected
AP28	M	45+	R antrum covered with remodelled pitted NBF
AP96	SA	6-8	Both antra and walls with remodelled spiculated NBF

Appendix C6, Table 7 Apple Down. Individuals with maxillary sinusitis.

No.	Sex	Age	Description
CS30	F	36-45	R sinus with remodelled spiculated NBF on wall
CS7	F	45+	R sinus wall with small patch of remodelled spiculated NBF
CS19B	M	36-45	R antrum with remodelled spiculated NBF
CS63	M	45+	L antrum with small spiculated remodelled NBF

Appendix C6, Table 8 Castledyke South. Individuals with maxillary sinusitis.

No.	Sex	Age	Description
NT41	F	16-25	R maxillary sinus with grossly spiculated (remodelled) NBF on roof, less marked spicules on antrum; L sinus with small areas of spiculated, remodelled NBF both on roof and antrum
NT99	F	16-25	Sinuses with spiculated, remodelled NBF and pitting on antrum
NT57	F	26-35	Small area of spiculated, remodelled NBF on antrum of L sinus
NT113	F	36-45	L maxillary sinus with spiculated NBF (3.8x4.5 mm) on antrum
NT106	F	45+	Both maxillary antra with pitting
NT91	M	16-25	R maxillary sinus with spiculated, remodelled NBF on wall, pitting on antrum; L maxillary sinus normal but frontal sinuses affected
NT29	M	26-35	L maxillary sinus with spiculated NBF (remodelled) on roof of sinus (antrum not preserved)
NT42	M	adult	R maxillary sinus consists of three compartments separated by thin bony walls. Spiculated (remodelled), pitted NBF on antrum of posterior compartment; roots of 1st molar penetrated into medial compartment, while roots of 2nd molar are visible within anterior compartment. L maxillary sinus with spiculated NBF and pitting around roots of 2nd molar, which reaches into sinus

Appendix C6, Table 9 Norton. Individuals with maxillary sinusitis.

No.	Sex	Age	Description
NE52	F	16-25	Both sinuses with remodelled spiculated NBF on antrum
NE148-1	F	16-25	Some remodelled spiculated NBF on both antra
NE5	F	26-35	L and R antrum with remodelled spiculated NBF
NE8-1	F	26-35	Antrum of L maxillary sinus with remodelled spiculated NBF and perforation from root of 1st molar
NE73	F	26-35	Both sinuses with remodelled spiculated NBF – roots of maxillary molars penetrating sinuses
NE76	F	26-35	Both maxillary sinuses with remodelled spiculated NBF on antrum and on R walls
NE96	F	26-35	R maxillary sinus with remodelled NBF on antrum and roof – porous spiculated bone
NE124	F	26-35	L sinus with small area of remodelled spiculated NBF on wall
NE131	F	26-35	R sinus with lamellar pitted NBF on antrum
NE143	F	26-35	Both sinuses with patches of remodelled spiculated NBF on antrum and walls (L sinus; R only part of antrum preserved)

NE147	F	26-35	Both antra with slight remodelled spiculated NBF
NE149	F	26-35	Antrum of L sinus with some porous woven NBF
NE22-1	F	36-45	L sinus with spiculated NBF (active)
NE70	F	36-45	Remodelled spiculated NBF on antrum of L sinus
NE98	F	36-45	L sinus with small area of remodelled spiculated NBF on antrum and roof
NE99	F	36-45	Both sinuses with remodelled spiculated NBF on antrum
NE145	F	36-45	Two small osteophytes around pinprick sized perforation of L maxilla (resorbed alveolar socket of 2nd molar)
NE106	F	45+	R sinus with remodelled spiculated NBF and porosity
NE72	M	16-25	Both maxillary sinuses with small area of remodelled spiculated NBF
NE134	M	16-25	Both sinuses with remodelled spiculated NBF on antrum
NE139-2	M	16-25	L sinus with remodelled spiculated NBF on entire antrum; perforated by abscess. Additionally, frontal sinusitis
NE68	M	36-45	R side – wall and antrum completely covered with remodelled porous NBF; L sinus with small patches of remodelled spiculated NBF
NE78-2	M	36-45	L sinus with remodelled, slightly pitted NBF
NE84	M	36-45	R maxillary sinus with remodelled, spiculated NBF on wall (small area) and antrum (covering entire antrum). Additionally, frontal sinusitis
NE97	M	36-45	R sinus covered with remodelled spiculated and pitted NBF
NE126-1	M	36-45	Both sinuses with remodelled spiculated NBF on antrum and L walls
NE79	M	45+	R antrum with remodelled spiculated and pitted NBF
NE120	M	45+	Both sinuses with remodelled spiculated and pitted NBF on antra
NE128	M	45+	L antrum with remodelled spiculated NBF
NE140-2	M	adult	R maxillary wall thickened with dense, slightly pitted NBF and few remodelled spicules – antrum not preserved
NE132-1	SA	2-4	Both antra with remodelled spiculated NBF
NE146	SA	12-14	Some remodelled spiculated NBF on antrum of L sinus

Appendix C6, Table 10 Neresheim. Individuals with maxillary sinusitis.

No.	Sex	Age	Description
NU17-1	F	16-25	L and R posterior antrum with finely pitted remodelled NBF
NU106	F	16-25	R antrum with woven pitted NBF
NU9-1	F	16-25	L maxillary sinus wall with patch of remodelled spiculated NBF
NU86	F	26-35	R antrum and wall with remodelled spiculated NBF
NU128	F	26-35	L antrum with one remodelled spiculated NBF
NU71	F	36-45	Both maxillary sinuses (L wall and antrum, R wall) with spiculated remodelled NBF
NU101	F	36-45	Both walls with very small patches of remodelled spiculated NBF
NU155	F	36-45	R antrum with small patches of remodelled spiculated NBF, pitting around perforation by abscess at root of 1st premolar
NU31	F	45+	L antrum with pitting and remodelled dense NBF
NU116	M	16-25	L antrum and wall with extended areas of woven pitted NBF
NU132	M	26-35	Both walls with small patch of remodelled spiculated NBF
NU214	M	26-35	Both antra and walls covered with pitted remodelled NBF; palate pitted as well
NU25	M	36-45	L sinus (antrum and wall) with remodelled spiculated NBF
NU76	M	36-45	L wall with remodelled striated NBF
NU109	M	36-45	L antrum and walls covered with extensive spiculated and nodular sometimes pitted remodelled NBF

NU178	M	36-45	L antrum and wall covered with remodelled spiculated NBF
NU47	M	45+	L maxillary sinus with small patch of remodelled striated NBF
NU131	M	adult	Both walls and antra covered with remodelled pitted NBF
NU1244	M	adult	Both walls with tiny flecks of remodelled spiculated NBF
NU42	N/D	36-45	R sinus (antrum and wall) covered with dense pitted NBF; L antrum with fine dense pitting
NU13	N/D	adult	R antrum with pitted remodelled NBF
NU14-1	N/D	adult	L wall with patch of remodelled spiculated NBF; L antrum with perforation by lingual root of 1st molar – raised thin-walled bony cyst with very fine pitting
NU22-2	N/D	adult	R antrum with very fine remodelled pitting around perforation from root of 2nd premolar
NU35-2	N/D	adult	L Wall with two larger patches of remodelled spiculated NBF
NU93-3	N/D	adult	L antrum with pitted remodelled NBF
NU114-2	N/D	adult	R maxillary sinus – wall with few remodelled spiculated NBF
NU202	SA	14-16	Both antra with woven spiculated NBF

Appendix C6, Table 11 Nusplingen. Individuals with maxillary sinusitis.

No.	Sex	Age	Description
PL4	F	16-25	L antrum and R wall with remodelled spiculated NBF
PL89	F	16-25	L antrum and wall with remodelled spiculated NBF
PL16B	F	26-35	Both antra and L wall with spiculated remodelled NBF
PL84	F	26-35	R wall and antrum with small patches of remodelled spiculated NBF
PL105	F	26-35	Both antra and R wall with remodelled spiculated NBF
PL51	F	36-45	R antrum with remodelled spiculated NBF
PL86	F	36-45	L wall with few spiculated remodelled NBF
PL115	F	36-45	R wall with few remodelled spicules
PL141	F	36-45	R antrum with remodelled spiculated NBF
PL59	F	45+	R antrum with remodelled spiculated NBF
PL106	F	45+	Both antra and R wall with remodelled spiculated and pitted NBF. Additionally, frontal sinusitis
PL5	F	adult	L antrum with spiculated remodelled NBF; antrum perforated by root of 2nd molar
PL56B	M	36-45	Both antra with remodelled spiculated NBF
PL82	M	36-45	R wall covered with woven pitted NBF
PL116	M	36-45	R antrum and wall with remodelled spiculated NBF

Appendix C6, Table 12 Pleidelsheim. Individuals with maxillary sinusitis.

Site	Sex	Age	Description
AP68	M	26-35	One R rib with pinprick-sized dense NBF on internal aspect – irregular surface
AP123	M	26-35	Some visceral ribs with irregular cortex
AP122	M	36-45	Ossified pleura found between ribs and sternum – thin plate-like structure with irregular uneven surface. Most ribs with irregular nodular NBF on inferior visceral aspect. L 1st rib with thickened sternal end and some ossified cartilage
AP152	M	26-35	All ribs of R side with mixed NBF (pitted and striated); on sternal ends more woven than striated
CS98	M	16-25	Visceral surface of ribs with remodelled NBF
CS72	M	26-35	Two L and two R ribs with off-white coloured porous remodelled NBF on visceral aspect of costal angle. Some rib fragments with dense nodular NBF on visceral surface of costal body

CS19A	M	36-45	Some rib frags with remodelled irregular small nodules on visceral surface
CS151	SA	10-12	Porous woven NBF on visceral surface of ribs
NE78-1	F	36-45	L 1st rib with irregular thickening of sternal end and large exostosis articulating with manubrium. On inferior aspect fine pitting. 2nd R rib – sternal end and body thickened with finely pitted but remodelled NBF. L rib – tubercle destroyed by lytic lesion leaving irregular remodelled cavities. Five costal bodies with dense remodelled nodular NBF on visceral surface
NE32	M	26-35	Visceral surface of most ribs with dense remodelled NBF
NE97	M	36-45	Unsided costal body with small (1.0 mm) circular dense remodelled NBF on ventral aspect
NU166	F	26-35	Five L ribs – visceral surface – with dense nodular small NBF; seven R ribs with woven pitted NBF on visceral aspect of angle, one unsided rib fragment with woven pitted NBF on visceral aspect
PL106	F	45+	Six R ribs with woven pitted NBF at visceral aspect of necks. Two thoracic vertebrae with lytic scalloped lesions; trabeculae remodelled and disorganized

Appendix C6, Table 13 Individuals with new bone formation on visceral surfaces of ribs.

No.	Sex	Age	Description
AP39	M	26-35	Lytic area left of frontal crest filled with remodelled spiculated NBF. More lytic clusters adjacent to sagittal suture. Small (ca. 6.0 mm) circular lytic lesion with raised and remodelled margin on L parietal adjacent to sagittal suture
AP152	M	26-35	Frontal and both parietal bones with off-white areas of vessel impressions
AP99B	M	45+	Frontal bone with small osteophytes adjacent to mid-line; on frontal crest area of whitish pitted (woven) NBF (7.0x15.0 mm)
NE141-5	F	26-35	L frontal bone ca. 2.0 cm L of superior end of frontal crest – shallow irregular depression (9.5x12.4 mm) filled with irregular plaque-like NBF – dense but irregular surface (7.0x9.7 mm)
NE120	M	45+	Both internal temporal bones – superior fossa – at base of petrous parts small spicules of lamellar bone
NU107	F	16-25	Internal frontal bone with continuous layer of greyish but remodelled pitted NBF in continuation with frontal crest
NU168	F	26-35	Internal frontal and R parietal bone with excessive layer of woven pitted NBF
NU61	F	36-45	Internal frontal bone with two raised areas of dense oval NBF and several flat patches of NBF; small vessel impressions on frontal and both parietal bones as well as both orbital roofs
NU101	F	36-45	Internal occipital bone – centre of cruciform eminence – with cluster of remodelled pits (ca. 0.2 mm diameter)
NU116	M	16-25	Internal frontal with large areas of high vascularity symmetrically adjacent to frontal crest (ca. 2.5 cm distance)
NU139	M	16-25	Fine vessel impressions and some fine remodelled pitting at interior occipital – cruciform eminence
NU130	M	36-45	Fine remodelled pitting and fine worm-like vessel impressions on internal occipital (cruciform eminence) and along sagittal suture; internal frontal with few spicules L of frontal crest
NU95-2	SA	3-5	Internal occipital with worm-like vessel impressions at cruciform eminence
PL108	F	adult	Internal frontal with fine vessel impressions
PL56B	M	36-45	Frontal bone (adjacent to frontal crest) vertical vessel impressions

PL119	SA	3-5	L internal frontal bone with circular area (6.6 mm) of spiculated, woven NBF
PL6	SA	8-10	Woven pitted NBF on internal frontal (along frontal crest) and both inferior aspects of internal temporal bones, R sphenoid with small irregular patches

Appendix C6, Table 14 Individuals with new bone formation and/or vessel impressions on the ectocranial surface of the skull.

APPENDIX C7 CONGENITAL AND DEVELOPMENTAL ANOMALIES

No.	Sex	Age	Description
AP108	F	16-25	Four sacral segments, five lumbar vertebrae
AP49	F	26-35	S1 only fused to S2 on anterior R side; posterior aspect shows some degree of fusion between facets (S1=L6)
AP52	F	26-35	S1 only fused on R anterior side to S2 (S1=L6)
AP115B	F	26-35	13 thoracic vertebrae, lumbar ribs
AP128	F	26-35	13 thoracic vertebrae, lumbar ribs
AP162	F	26-35	Congenitally absent costal articular facets on T9, T10 and T12
AP48	F	36-45	Two cervical ribs on C7
AP19	M	26-35	Sacrum with six segments, five lumbar vertebrae
AP25B	M	26-35	Sacrum with six segments, five lumbar vertebrae
AP12B	M	45+	Six lumbar vertebrae, five sacral segments
AP22	M	45+	Six lumbar vertebrae, five sacral segments
AP31	M	45+	Six lumbar vertebrae, five sacral segments
CS31	F	16-25	S1 partially separated
CS67	F	26-35	S1 resembles lumbar vertebra; inferior articular facets not entirely fused to sacral body
CS173	F	26-35	S1 resembles lumbar vertebra although fully fused
CS30	F	36-45	Six lumbar vertebrae
CS73	F	36-45	Six sacral segments
CS163	F	36-45	L5 fused to sacrum (only four lumbar vertebrae)
CS158	M	16-25	Sacralisation: S1=lumbar vertebra; fused on R side only
CS186	M	16-25	S1 resembles lumbar vertebra
CS103	M	26-35	Four sacral elements, six lumbar vertebrae
CS38	M	36-45	L5=S1, although not observable how many sacral elements were present (only four true lumbar vertebrae)
CS66	M	36-45	Lumbar ribs
CS180	M	36-45	Sacralisation: six sacral segments
CS147	M	45+	Lumbarisation: S1 fused anteriorly, posterior aspect of body open
NT107	F	16-25	Six lumbar vertebrae
NT37-1	F	adult	Sacrum with six segments
NT69	M	26-35	Sacrum with six segments
NE59	F	26-35	L5 corpus bipartite with circular perforation in centre (14.0 mm) – bipartite butterfly vertebra – *chorda dorsalis*
NE67	F	36-45	Lumbar rib (L aspect of L5) – 35.1 mm long with pointed tip; R side post-mortem damage
NE85	F	36-45	Sacrum with six segments
NE44	M	26-35	Sacrum with four segments
NU189	F	36-45	S1 completely fused but posteriorly lower facet rudiments visible
NU139	M	16-25	Six lumbar vertebrae
NU41	M	26-35	Fenestration on L side between posterior S1/2
NU112	M	26-35	L6 partially fused to sacrum (L side) with development of superior aspect of L sacral facet and superior aspect of 1st L sacral foramen. Inferior facets post-mortem damage. 2nd pair of sacral facets on S1
PL12	M	26-35	S1 only partially fused to S2; body unfused, separate inferior articular facets
PL40	M	36-45	R 2nd rib with broadened body; 3rd rib resembles 2nd
PL72	M	36-45	R superior facet of atlas fused to occipital condyle
PL82	M	36-45	L5=S1 additional articular facet on R aspect – partial fusion

Appendix C7, Table 1 Congenital diseases of the vertebral column (other than spina bifida occulta).

No.	Sex	Age	Skeletal element
AP128	F	26-35	S1-5
AP55	F	36-45	C1
CS134	F	16-25	Coccyx
CS183	F	16-25	S1-5
CS73	F	26-35	S5-6
CS23	F	36-45	S1-5
CS75	M	16-25	S1-2
CS98	M	16-25	S1
CS186	M	16-25	S1
CS33B	M	36-45	S1-2
CS90	M	36-45	C1
CS180	M	36-45	S6
NT37-1	F	adult	S4-6
NT69	M	26-35	S1-2,4-6
NE75	F	36-45	S1-5
NE85	F	36-45	S1-2,4-6
NE51	M	26-35	S1-2
NU27	F	26-35	S3-5
NU137	F	26-35	C1
NU3-1	F	36-45	S1,4-5
NU82	M	16-25	T11
PL139	F	26-35	S1
PL39	M	16-25	S1,3-5, S2 with fissure
PL44	M	16-25	S1-2,4-5
PL71	M	26-35	S1-3
PL40	M	36-45	S3-5
PL7B	M	adult	S1-5

Appendix C7, Table 2 Individuals with spina bifida occulta.

APPENDIX C8 METABOLIC DISEASE

No.	Sex	Age	Description
AP14	F	36-45	Slight remodelled pitting in both orbital roofs (stage I/II)
AP28	M	45+	Both orbital roofs with coalescent pitted NBF (stage III)
AP80	SA	4-6	Fine pitting on L orbital roof (stage I)
AP70	SA	5-7	Few fine pits on both orbital roofs (stage I)
AP82	SA	10-12	Sporadic fine pitting on R orbital roof (stage I)

Appendix C8, Table 1 Apple Down. Individuals with cribra orbitalia.

No.	Sex	Age	Description
CS187	F	26-35	L orbital roof with few fine remodelled pits (stage I/II)
CS84	M	16-25	Both orbital roofs with medium-sized remodelled pitting, some coalescence (stage III/IV)
CS36	M	36-45	L orbital roof with remodelled pitting (stage I/II)
CS20	SA	6-8	R orbital roof with very fine remodelled pitting (stage I); L with slight remodelled pitting (stage II)
CS80	SA	1-3	Both orbital roofs with medium-sized remodelled pits, some coalescence (stage III/IV)
CS165	SA	2-4	L orbital roof with fine remodelled pitting (grade I/II)
CS37	SA	5-7	L orbital roof with few fine remodelled pits (stage I/II)
CS181	SA	10-12	Both orbital roofs with fine remodelled pitting (stage II)
CS184A	SA	12-14	Fine remodelled pitting on L orbital roof (stage II)

Appendix C8, Table 2 Castledyke South. Individuals with cribra orbitalia.

No.	Sex	Age	Description
NT16	SA	10-12	Remodelled pitting on both orbital roofs, L orbit with more and larger pitting than R (stage II)

Appendix C8, Table 3 Norton. Individual with cribra orbitalia.

No.	Sex	Age	Description
NE148-1	F	16-25	L orbital roof with remodelled pitting (stage II)
NE16	F	26-35	L orbital roof with fine pitting, some coalescence (remodelled) – stage (III/IV)
NE46	F	26-35	Slight porosity on both orbital roofs, but no raised trabeculae (stage I/II) - remodelled
NE96	F	26-35	L orbital roof with vessel impressions and few fine pits (stage I)
NE100	F	26-35	L orbital roof with remodelled fine pitting and some vessel impressions (stage I)
NE133	F	26-35	Both orbital roofs with fine remodelled pitting (stage I) and vessel impressions
NE140-1	F	26-35	Both orbital roofs with fine remodelled pitting (stage I) and vessel impressions
NE99	F	36-45	L orbital roof with very few small pits (stage I)
NE3-2	F	45+	Both orbital roofs with very few remodelled pits (I/II)
NE43	F	45+	Both orbital roofs with very fine pitting (stage I) and vessel impressions
NE54	F	45+	R orbital roof with few fine remodelled pits (stage I/II) and vessel impressions
NE81	F	45+	Both orbital roofs with fine remodelled pitting and vessel impressions (stage I)
NE134	M	16-25	Both orbital roofs with fine remodelled pitting (L=stage II), R with

			cluster of larger pits (R=stage II/III)
NE10	M	26-35	L orbital roof with very few fine pits (grade I/II)
NE32	M	26-35	L orbital roof with remodelled pitting (stage I/II)
NE74	M	26-35	R orbital roof with few fine remodelled pits (stage I/II)
NE77	M	26-35	Both orbital roofs with fine remodelled pitting – R side more severe (stage II/III)
NE80	M	36-45	L orbital roof with fine remodelled pitting (stage I); R with remodelled coalescent pitting (stage IV)
NE97	M	36-45	Both orbital roofs with fine remodelled pitting (stage I) and vessel impressions
NE136	M	36-45	L orbital roof with remodelled pitting (stage II/III)
NE15	M	45+	Both orbital roofs with fine remodelled pitting and remodelled NBF (stage I)
NE40	M	45+	Both orbital roofs with remodelled pitting (stage II), vessel impressions
NE45	M	45+	L orbital roof with few fine remodelled pits (stage II)
NE79	M	45+	R orbital roof with few fine remodelled pits (stage I) and vessel impressions
NE89	M	45+	Both orbital roofs with fine pitting (stage I) and vessel impressions
NE102	M	45+	Both orbital roofs with remodelled pitting (stage II/III)
NE118	M	45+	Very fine remodelled pitting on orbital roofs (stage I)
NE128	M	45+	Both orbital roofs with very fine remodelled pitting and some vessel impressions (stage I)
NE93	SA	6-12m	R orbital roof with clustered fine pitting – remodelled (stage II)
NE119	SA	1-2	R orbital roof with fine pitting (active) (stage I)
NE95	SA	1.5-2.5	Both orbital roofs pitted, some coalescent pits (stage III/IV) - remodelled
NE13	SA	2-4	L orbital roof with fine remodelled pitting (stage II)
NE33	SA	2-4	R orbital roof with extreme coalescent pitted NBF – raised trabeculae (stage IV) L equally affected but only small area – active lesions
NE86	SA	2-4	L orbital roof with remodelled pitting; R with woven, grey NBF and pitting (stage II)
NE132-1	SA	2-4	Both orbital roofs with remodelled pits (R=stage III; L=stage III/IV)
NE1-1	SA	6-8	Both orbital roofs with remodelled pitting (stage II)
NE69	SA	6-8	Very few finely pitted lesions on both orbital roofs (stage II), R orbit with small spiculated remodelled NBF on medial aspect
NE114	SA	6-8	Both orbital roofs with remodelled pitting (L more severe than R) (stage II/III)
NE150	SA	8-10	L orbital roof with coalescent active pitting, R orbital roof with severe coalescent active pitting and raised trabeculae (L=stage III/IV), R=stage IV)
NE19	SA	10-12	L orbital roof with few fine remodelled pits (stage II)
NE60	SA	10-12	Both orbital roofs with few fine remodelled pits (stage I/II)
NE146	SA	10-12	Both orbital roofs with some remodelled pitting; L orbit with remodelled spiculated NBF (stage II)
NE23-1	SA	14-16	R orbital roofs with remodelled pitting (stage I/II)

Appendix C8, Table 4 Neresheim. Individuals with cribra orbitalia.

No.	Sex	Age	Description
NU105	F	16-25	Both orbital roofs with coalescent pitting (stage IV)
NU107	F	16-25	Both orbital roofs with remodelled coalescent pitting (stage IV)
NU194	F	16-25	R orbital roof with small and large remodelled pits (stage II/III)

NU35-1	F	26-35	Both orbital roofs with coalescent remodelled pitting (stage IV)
NU39	F	26-35	Both orbital roofs with coalescent pitting (stage IV)
NU45	F	26-35	Both orbital roofs with large but few remodelled pits (stage III)
NU65	F	26-35	Both orbital roofs with large, sometimes coalescent pitting (grade III/IV)
NU86	F	26-35	Both orbital roofs with coalescent pitting (stage IV)
NU137	F	26-35	L orbital roof with remodelled pitting (stage III); R orbit not affected
NU238	F	26-35	Very slight remodelled pitting on orbital roofs (stage I)
NU8-1	F	36-45	L orbital roof with few fine remodelled pits (stage I)
NU101	F	36-45	Both orbital roofs with pitting and some coalescent pits (stage III/IV)
NU213-1	F	36-45	Both orbital roofs with very fine pitting (stage I)
NU227	F	36-45	L orbital roof with coalescent pitting (stage IV), R orbital roof with few larger holes (stage III)
NU110	M	16-25	Both orbital roofs with remodelled pitting (L stage III/IV, R stage I)
NU36-2	M	26-35	Both orbital roofs with remodelled coalescent pitting (stage IV)
NU112	M	26-35	Both orbital roofs with remodelled larger pits (stage III)
NU208-1	M	26-35	Both orbital roofs with few larger pits (stage III)
NU1209	M	26-35	L orbital roof with few larger remodelled pits (stage III); R orbital roof normal
NU109	M	36-45	Very fine remodelled pitting on both orbital roofs (stage I)
NU178	M	36-45	L orbital roof with fine remodelled pitting (stage II); R normal
NU180	M	36-45	Both orbital roofs with few fine remodelled pits (stage II)
NU201	M	36-45	Both orbital roofs with coalescent remodelled pitting (stage IV)
NU214	M	36-45	Both orbital roofs with very fine remodelled pitting (stage I)
NU225	M	36-45	Both orbital roofs with coalescent pitting (stage IV)
NU241	M	36-45	Both orbital roofs with coalescent pitting (stage IV)
NU173	M	45+	Both orbital roofs with few large remodelled pits (stage III)
NU114-2	N/D	adult	Both orbital roofs with few fine pits (stage II)
NU199-1	SA	2-3	Both orbital roofs with few fine remodelled pits (stage II)
NU103	SA	2-4	Both orbital roofs with small and larger remodelled pits (stage II/III)
NU192	SA	6-8	L orbital roof with severe pitting – ranging from tiny to coalescent (stage III/IV)
NU122	SA	8-10	Both orbital roofs with woven trabecular NBF (grade V)
NU20	SA	10-12	Both orbital roofs with few fine remodelled pits (stage I/II)

Appendix C8, Table 5 Nusplingen. Individuals with cribra orbitalia.

No.	Sex	Age	Description
PL16A	F	16-25	L orbital roof with few fine remodelled pits (stage I); R orbital roof with more and larger remodelled pitting (stage II)
PL32	F	16-25	Both orbital roofs with remodelled coalescent pitting (stage IV)
PL16B	F	26-35	R orbital roof with few larger remodelled lytic lesions (stage II)
PL106	F	45+	R orbital roff with vessel impressions and few fine pits (stage I)
PL39	M	16-25	L orbital roof with few larger remodelled pits (stage II), R with few fine remodelled pits (stage I)
PL125	M	16-25	L orbital roof with remodelled coalescent pitting (stage IV); R orbital roofs with very few fine remodelled pits (stage I)
PL127	M	26-35	Vessel impressions on both orbital roofs, few fine pits (stage I)
PL124	M	36-45	L orbital roof with few remodelled fine and larger pits (stage II) – R not affected
PL48	SA	1-2	R orbital roof with many small remodelled pits (stage I)

PL58	SA	1-2	Both orbital roofs with few fine remodelled pits (stage I)
PL53	SA	2-4	Both orbital roofs with remodelled coalescent pitting (stage IV)
PL73	SA	2-4	Both orbital roofs with active raised coalescent pitting (stage V)
PL112	SA	2-4	Minimal remodelled pitting on R orbital roof (stage I)
PL119	SA	2-4	Both orbital roofs with few fine remodelled pits (stage I)
PL33	SA	10-12	Both orbital roofs with active raised coalescent pitting (stage V)
PL54	SA	10-12	Both orbital roofs with fine remodelled pitting (stage I)
PL132	SA	10-12	L orbital roof with remodelled fine and larger pits (stage III), R orbital roof with few fine remodelled pits (stage I)
PL114	SA	14-16	Minimal remodelled pitting at both orbital roofs (stage I)
PL121	SA	14-16	Scattered remodelled fine and larger pits on both orbital roofs (stage II)

Appendix C8, Table 6 Pleidelsheim. Individuals with cribra orbitalia.

No.	Sex	Age	Description
NE9-1	F	26-35	Distal radius – Colles' fracture
NE109	M	45+	Distal radius – Colles' fracture
NU102	F	16-25	Proximal femur – neck fracture
NU93-2	M	26-35	Distal radius – Colles' fracture
PL71	M	26-35	Proximal femur – neck fracture
PL79	M	45+	Distal radius – Colles' fracture

Appendix C8, Table 7 Individuals with possible osteoporosis – distal radius (Colles') and femoral neck fractures.

No.	Sex	Age	Description
AP120	F	26-35	L5 wedge-shaped body
AP14	F	36-45	L1 wedge-shaped body
AP33	F	36-45	T11 wedge-shaped body
AP48	F	36-45	L5 wedge-shaped body
AP55	F	36-45	L5 wedge-shaped body
AP71A	F	36-45	L5 wedge-shaped body
AP84	F	36-45	L1 wedge-shaped body
AP19	M	26-35	T11 depressed body
AP68	M	26-35	L3+4 wedge-shaped body
AP148B	M	26-35	T11+12 wedge-shaped bodies
AP152	M	26-35	L1-L5 wedge-shaped body
AP28	M	45+	T11+12 wedge-shaped bodies
AP99B	M	45+	L1 wedge-shaped body
CS23	F	36-45	L5 wedge-shaped body
CS30	F	36-45	T8, L5 wedge-shaped bodies
CS95	F	36-45	L1-4 compressed bodies; L5 wedge-shaped body
CS135	F	36-45	L3 compressed body
CS138	F	36-45	L1-5 wedge-shaped bodies
CS160	F	36-45	L5 wedge-shaped body
CS26	F	45+	T4,T9-12 compressed bodies; L4+5 'cod-fish' vertebrae
CS115	F	45+	L5 compressed body
CS166B	F	adult	L2 compressed body
CS9	M	26-35	L4+5 wedge-shaped bodies
CS33B	M	36-45	L5 compressed body
CS108	M	36-45	L2-5 compressed bodies
CS180	M	36-45	L5 compressed body
CS147	M	45+	L1-5 compressed body
NT98	F	26-35	L5 compressed body

NE127	F	26-35	L3 compressed body
NE147	F	26-35	L5 wedge-shaped body
NE67	F	36-45	L5 compressed body
NE29	M	36-45	L4+5 wedge-shaped bodies
NE61-1	M	36-45	L4 compressed body
NE136	M	36-45	L2 wedge-shaped body
NE102	M	45+	L5 wedge-shaped body
NU166	F	26-45	L5 compressed body
NU3-1	F	36-45	L5 compressed body
NU23	F	36-45	T5-7 wedge-shaped
NU71	F	36-45	L5 wedge-shaped body
NU155	F	36-45	L4 compressed body
NU169	M	16-25	L4+5 wedge-shaped bodies
NU173	M	45+	L5 compressed body
PL115	F	36-45	L4+5 wedge-shaped bodies
PL135	F	36-45	L5 wedge-shaped body
PL110	F	adult	T5, T7+8 wedge-shaped bodies
PL12	M	26-35	L3 compressed bodies
PL102	M	26-35	L5 wedge-shaped body
PL113	M	36-45	L5 wedge-shaped body
PL10	M	adult	L3, L5 compressed bodies

Appendix C8, Table 8 Individuals with possible osteoporosis – vertebral body fractures.