The validity and inter-relationship of subjective and objective measurements of stiffness in human joints

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THE VALIDITY AND INTER-RELATIONSHIP OF SUBJECTIVE AND OBJECTIVE MEASUREMENTS OF STIFFNESS IN HUMAN JOINTS

Valerie M. Rhind

ABSTRACT

Rheumatoid arthritis is a chronic, progressive, inflamatory disease characterised by pain, stiffness, swelling and loss of function. Severity of these symptoms is extremely variable both between patients and over time in individual patients. Assessment of disease activity and response to treatment relies heavily on subjective assessments of pain and stiffness and non-specific biochemical measures.

In this study an arthrograph has been used to measure stiffness objectively at the right index metacarpal-phalangeal joint. Stiffness was defined as resistance to motion in the flexion / extension plane of movement. The finger was moved through 40 degrees, centred on the equilibrium position. Stiffness was quantified in terms of resistive torque, dissipated energy and angles of the hysteresis loop slope in flexion, extension and mid range positions. Principal components analysis was later used to create an 'objective stiffness factor' from these readings.

Grip strength, proximal inter-phalangeal joint size and total hand size were measured in all study subjects. Patients with rheumatoid disease were asked to assess the severity of their pain and stiffness using numerical rating scales and to record the duration of their morning stiffnes. Joint tenderness was assessed using an articular index; plasma viscosity and haemoglobin estimation were recorded.

One hundred healthy women and eighty five women with rheumatoid disease were each assessed on one occassion. Thirteen healthy women and twenty six women with rheumatoid disease agreed to be assessed monthly for one year.

Objective stiffness was found to be influenced by size of the pip joints. It bore little relationship to patient's subjective assessment of stiffness and did not differentiate between patients and healthy control subjects. Patient's assessment of their symptoms was mainly influenced by joint tenderness and grip strength.

These findings support the suggestion that difficulty of movement, due to pain and weakness, is being misinterpreted as stiffness by patients with active rheumatoid disease.

No human investigation can be called true science without passing through mathematical tests.

Leonardo da Vinci

THE VALIDITY AND INTER-RELATIONSHIP OF SUBJECTIVE AND OBJECTIVE MEASUREMENTS OF STIFFNESS IN HUMAN JOINTS

by

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INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Rheumatoid arthritis is a chronic, progressive inflamatory disease affecting approximately 3% of the population with females accounting for 70% of the cases. The disease is characterised by pain, stiffness and swelling of the joints. There is also fatigue, loss of strength, weight loss and other signs of systemic illness such as anaemia and raised plasma viscosity. The severity of these symptoms is extremely variable both between patients and over time in individual patients. Severity of the individual symptoms does not necessarily change at the same rate or time so that, when devising a scheme for evaluation, no single symptom can be relied upon exclusively.

Pain, stiffness and loss of strength have been shown to follow a circadian pattern of change, and it has been suggested that they may also follow a monthly cyclical rhythm in females and be affected by changes in the weather. This naturally occuring variation in severity requires prolonged accurate assessment of the symptoms in order to monitor the course of the disease, evaluate different treatments and assess

their impact on the overall progression of the disease. It is therefore important that the methods used to measure these symptoms are sensitive, reliable, valid, quick and easy to perform and not susceptible to inter- or intra-observer error. Subjective rating scales have become the accepted method of measuring pain and stiffness in most clinical trials in rheumatology. These scales are simple and quick to use but, as has been pointed out by several investigators, they are open to misunderstanding and misinterpretation by the patients and the results obtained by this method can never be regarded as more than an approximation of how severe the patient perceives his symptoms to be. The patients' perceptions of their symptoms may be influenced by mood, past experience, duration of disease and their expectations of the present treatment. It is also clear that many patients are unable to assess the severity of their pain and stiffness separately. They may confuse stiffness with reduced range of movement, pain on movement or weakness.

Various methods have been devised to measure pain and stiffness objectively, but none is currently in general use. This work aims to investigate the validity and relevance of an objective measurement of

stiffness in comparison with other measurements of disease activity more frequently used in the clinical situation.

CHAPTER 1

MEASUREMENT OF PAIN

Pain is a subjective, sensory and affective experience. It is felt by all of us but everyone has their own way of expressing it. It is usually expressed by a combination of overt pain behaviour such as grimacing, rubbing, bracing, guarding, sighing etc. and verbal descriptions such as burning, dull, stabbing, nagging etc., as well as descriptions of intensity. This makes pain impossible to define in a precise, universally acceptable way and difficult to measure by anyone other than the sufferer.

Melzack (1975) studied the language of pain and produced the McGill Pain Questionnaire which measures pain by assigning severity ratings to the various descriptive words used by the patient. Wagstaff (1985), using a similar method found that descriptors of pain used by patients with rheumatic diseases were sufficiently sensitive to discriminate between the various closely related pain syndromes. However, other studies have found that patients' perception and self-reporting of pain are affected by depression and anxiety (Anderson, Bradley,

McDaniel et al. 1987). These authors also studied the pain behaviours displayed by patients with rheumatoid arthritis or low back pain and concluded that these were not related to affective disturbance.

As it is impractical to perform a psychological assessment of patients in a routine rheumatology clinic and both pain assessment questionnaires and observation of pain behaviour require a great deal of time to administer and interpret, various simple rating scales have been devised to allow patients to quantify their pain or pain relief.

PAIN RATING SCALES

Patients can be asked to describe their pain using words such as none, mild or slight, moderate, severe, very severe or agonising. A numerical value can then be assigned to their answer. Alternatively, pain relief scales can be used as no improvement, slight improvement, great improvement or pain free. These scales are very simple and are easily understood by most patients although Hill and Bird (1986) report that some individuals may have trouble deciding which word best describes their pain. The main disadvantage of this type of scale

is the lack of sensitivity, those patients with mild pain have only one possible grade of improvement - no pain, and those with very severe pain can only improve.

The numerical rating scale, with descriptive terms at each end only, allows greater sensitivity. The scale is usually 0 - 10 but may be 0 - 20 or greater. The patient is told that '0' represents no pain and the maximum number used represents maximum pain. He is then asked to assign a number to the amount of pain being experienced. This scale is simple to use and is easily understood by most patients.

The visual analogue scale allows the greatest sensitivity. A straight line, usually 10 cms in length, either vertical or horizontal, is presented to the patient. The ends are marked and labeled with descriptive terms, usually 'no pain' and 'very severe pain'. The patient is then asked to mark the point on the line which best represents the amount of pain being experienced. This scale is currently in widespread use in the assessment of anti-inflamatory and analgesic preparations but it should be used with caution. It is the most difficult for the patients to understand and use. It may require

repeated careful explanation by an experienced assessor before being used and its use can be profoundly affected by its design and presentation (Wright 1985). Some studies have shown good correlation between the vertical and horizontal visual analogue scales but others have shown that scores on the vertical scale tend to be higher than on the horizontal scale (Hinchcliffe, Surrall and Dixon 1985). Some patients interpret the scale, particularly the vertical scale as representative of their body and so mark neck pain high on the scale and ankle or foot pain at the bottom of the scale.

Repeated measurement of pain using the visual analogue scale has received much attention over the past few years with some arguing that patients should not be allowed to see their previous scores for comparison (Hart and Huskisson 1972) and others that, as patients usually express their pain in relation to their previous states, they should have access to their earlier assessments. Scott and Huskisson (1979) suggest that patients who are not allowed to see their original score tend to over-estimate on subsequent occasions, but Dawes and Haslock (1982) found that more than half their patients under-estimated on subsequent occassions.

There are obviously points for and against the use of each rating scale depending on the type of study being conducted. The visual analogue scale is potentially the most sensitive but it is also the most open to misinterpretation and error. The numerical rating scale is less sensitive than the visual analogue scale but more easily understood by the patients. It has been shown to reflect more accurately the patients verbal description of pain than either a vertical or horizontal visual analogue scale (Downie, Leatham, Rhind and Wright 1978). It does not pose problems of reproducibility. For these reasons a 0 - 10 numerical rating scale has been used in the current study to allow patients to quantify the severity of their pain and stiffness.

ARTICULAR INDEX

Pain caused by passive movement of a joint or by pressure applied to a joint margin, usually referred to as tenderness, is considered to be indicative of inflamation present in that joint. Its severity can be assessed by the patient using any of the pain rating scales previously discussed, but it is more usual for the person who applies the movement or pressure to assess the patient's reaction or simply to count the number of joints which are tender. The

Articular Index, as originally described by Ritchie, Boyles, McInnes et al., in 1968, is a system which grades the patient's response to passive movement of the cervical spine, the hip joints, the talo-calcaneal and the midtarsal joints and to firm pressure applied over the joint margins of the tempro-mandibular, sterno-clavicular, acromio-clavicular, shoulder, elbow, wrist metacarpal-phalangeal, proximal interphalangeal, knee, ankle and metatarsal joints. These are four possible grades: grade 0 - the patient has no tenderness; grade 1 - the patient complains of pain or tenderness; grade 2 - the patient also winces; grade 3 - the patient also withdraws the joint being tested. The articular index has been officially approved by EULAR (Lequesne, 1980) and is now commonly used in most studies of drug treatment in rheumatoid arthritis in this country. The Index of the Co-operating Clinics of the American Rheumatism Association (1967) advocates use of a similar system. Rhind, Bird and Wright (1980) found that the articular index, when assessed by one metrologist throughout the study, was the clinical assessment which best correlated with the biochemical indicators of disease activity. Kirwan, Barnes, Davies and Currey (1988) studied the effect of computer assisted feedback on the clinical

judgement agreement between three rheumatologists. Duration of morning stiffness, grip strength, pain (measured on a visual analogue scale), patients own global assessment of disease severity, a disability index and articular index were all recorded by a metrologist and a rheumatologist. The rheumatologist also recorded, on a visual analogue scale, his assessment of the patient's current disease activity. Using regression analysis, it was shown that the articular index was the predominating influence on each rheumatologist's clinical judgement of disease activity. In the study each patient's articular index was assessed by the metrologist and one of the rheumatologists but they do not state the level of agreement reached between the metrologist and each of the three rheumatologists. The original study of articular index by Ritchie et al. emphasised the need to use the same assessor throughout any study as there may be large inter-assessor variation. Lewis, O'Sullivan, Rumfeld, Coles and Jessop (1988) state that there was close agreement on total articular index score both within and between two trained metrologists but also state that their 95% confidence intervals for detecting a clinically significant change in an individual were $\pm$ 14 for one observer and $\pm$ 17 for two observers. Small

changes in score cannot therefore be interpreted, reliably especially if more than one observer is used during a study.

CHAPTER 2

MEASUREMENT OF SWELLING

Measurement of joint swelling is the only really objective clinical measurement commonly used in the assessment of rheumatoid disease activity.

The use of standard jewellers rings to measure the circumference of the proximal interphalangeal (pip) joints was first described by Hart and Clark in 1951. Using the 'Arthrocircameter' described by Willkens, Heyman (1974) demonstrated that in normal volunteers there was no difference in mean size between age groups in males or females. There was a small diurnal variation with the joints being larger in the morning than in the evening, and this variation was more obvious in the younger age groups. No variation attributable to the menstrual cycle was found in nine women studied. He concluded that a change of 2 mm or greater in any single joint is more than the normal variation.

Rudge and Drury (1981) studied change in pip joint size in relation to weight loss and recorded reductions of up to 9.4 mm, measured over 10 digits, per kg. weight loss. They also studied

change in pip joint size and grip strength throughout two menstrual cycles in six normal volunteers and seven patients with rheumatoid arthritis and recorded variations in total pip joint size between 7 mm (1.4%) and 86 mm (14.8%) using a metal spring gauge. In a later study they also demonstrated significant cyclical changes in body weight and grip strength in patients and normal volunteers (Rudge, Kowanko and Drury 1983). It is therefore necessary to interpret changes in pip size in relation to the state of the menstrual cycle and changes in body weight due to other causes.

Measurement of the pip joints, using various designs of arthrocircometer, has been shown to have small intra-observer error and to be sensitive to change, however, it has also been shown not to correlate well with other clinical and biochemical indices of disease activity (Rhind, Bird and Wright 1980). This may be because not all patients have active involvement of the pip joints at the time of assessment, and has led to the suggestion that only active joints should be measured. Dixon, Hill and Bird (1987) suggest that measurement of one joint, either the largest or 'worst', saves time on measurement without loss of accuracy or sensitivity. The disadvantage of this system is that in a long

term study if the chosen joint is no longer active but another one has become active it will not be considered.

The metacarpal-phalangeal (mcp) joints cannot be measured individually with an arthrocircometer. Helliwell (1987) measured finger circumference immediately distal to the web in order to assess the amount of tissue bulk at the mcp joint and found this measurement to be the predominating influence on objective stiffness variables measured on the Leeds microprocessor controlled arthrograph.

A method in which swelling of the entire hand may be measured by water displacement was described by Eccles (1956). His measuring apparatus consisted of a perspex tank with two outlets to syphon (sic) off the displaced water and a graduated measuring flask. He was able to measure hand volume with a margin of error of less than one per cent and to demonstrate changes in hand volume of up to 15 ml (5%) throughout the day in normal hands. Application of wax at temperatures of approximately 120 degrees F. for half an hour produced an increase in volume of 3 - 4% in normal hands but only 0 - 2% in already swollen hands. Hands with original swelling of more than 20% above normal were reduced in size by 3%

after treatment. Elevation of the swollen hand produced the greatest benefit but short wave diathermy for 20 minutes caused no measurable alteration in volume.

Smyth, Velayos and Hlad (1963) used a similar apparatus to measure swelling of the hands and feet and also reported a reproducibility error of less than one per cent. They found no significant difference between readings made at 8.30 am and 3.30 pm in normal subjects. One patient with rheumatoid arthritis was studied at the beginning of treatment with high daily doses of prednisone (20 mg daily) and during the subsequent three week period of dose reduction. During this time there was an initial reduction of 65 ml (11%) in hand volume, followed by a gradual increase (30 ml) as the dose was reduced and then another sustained reduction when the type of steroid was changed to paramethasone 8 mg daily. Marked and progressive reduction in foot volume was recorded in patients with gout following initiation of treatment with Indomethacin. In ten patients there was a mean reduction in size of 135 ml (9%) in the affected foot and 37 ml (2.5%) in the other foot.

This method of measuring swelling of the extremities

is simple to perform but has not achieved general use in rheumatology clinics, possibly because of the length of time needed to perform the measurement. It has a theoretical advantage over measurement of the pip joints only as all the joints which may be swollen are included in the measurement as well as any soft tissue swelling which may be present.

CHAPTER 3

MEASUREMENT OF GRIP STRENGTH

The strength of a patient's grip may be altered by the presence of pain, stiffness or swelling of the hand or wrist. It can be measured subjectively by the patient or objectively using a dynamometer or a computer controlled strain gauged device. This method of measurement is not totally objective as it requires the co-operation of the subject.

Downie, Leatham, Rhind, Wright et al. (1978), investigated a physicians ability to assess patients grip strength by asking them to squeeze his index and middle fingers, and the patients ability to assess their grip strength using a visual analogue scale. The patients grip was also measured on a dynamometer. The results showed that most patients failed to assess their strength correctly and the physician achieved a positive correlation in the 'normal' and 'strong' groups only. This emphasises the need to use an objective method of grip strength measurement, particularly with rheumatoid arthritis sufferers who tend to be weaker than normal.

Hunsicker and Donnelly (1955) reviewed the studies of strength measurement published since 1699 with particular reference to the various devices used. In 1939 Geckler developed a pneumatic dynamometer consisting of a rubber bulb connected to an air compressor gauge by means of a short metal tube. This device was later adapted by Wright (1959) to measure grip strength in patients with rheumatoid arthritis. He also used an elliptical spring steel dynamometer (the Smedley dynamometer) and a modified tensiometer for normal subjects (both devices are described by Hunsicker and Donnelly) and demonstrated a diurnal variation of grip strength in normal subjects and patients with rheumatoid arthritis. His study demonstrated a close correlation between body temperature and grip strength.

Lee, Baxter, Dick and Webb (1974) used an ordinary mercury column sphygmomanometer attached to a cloth covered rubber bag to measure grip strength and assess inter- and intra- observer error. They showed a marked inter-observer error (approximately 20 mm Hg) and a small intra-observer error (3 - 9 mm Hg mean difference), thus stressing the need to use the same observer throughout any study. Rhind, Bird and Wright (1980) demonstrated that, when a single

observer was used, grip strength was a sensitive indicator of disease activity and response to treatment. In patients with rheumatoid arthritis both grip strength and articular index had a significant correlation with C-reactive protein and erythrocyte sedimentation rate.

Electronic strain gauged devices were introduced as a more accurate method of measuring total or power grip, pinch grip and individual finger strength.

Dickson, Petrie, Nicolle and Colman (1972) used a digital cybernometer to measure individual finger flexion strength and demonstrated the relative strength of each of the digits. They report that the index finger was the strongest and the little finger the weakest. This finding agrees with that of Less, Krewer and Eickelberg (1977) who were also able to show a significant increase in little finger strength following isometric exercise of the intrinsic muscles of the hand, measured on a mechanical dynamometer.

Jones, Unsworth and Haslock (1985) used a variety of strain gauged devices linked to a microcomputer and arranged in such a manner as to measure forces applied in a number of everyday activities. These

included lifting a kettle and a saucepan and turning a key in a lock, as well as measuring total grip strength and individual finger strength. They found that the total grip strength and the forces exerted by individual fingers of the left and right hands were very similar even though the vast majority of subjects were right handed. The middle finger on each hand was found to be the strongest, contributing over a third of the total grip force. The ring finger contributed just under a third of the total grip force and the index and little fingers contributed roughly one sixth each. These results are consistent with those of Ohtsuki (1981). They also found that in normal volunteers lifting forces exceeded grip forces when lifting a kettle but were equal in patients with rheumatic diseases. When lifting a saucepan grip forces exceeded lift forces in both groups but were considerably lower in the patient group which probably explains why patients have such difficulty using ordinary saucepans and tea-pots.

Helliwell (1987) described and assessed a strain gauged torsion dynamometer linked to a microcomputer. He found that patients with rheumatoid arthritis had a maximum grip strength approximately 25% of the value for age and sex

matched controls, and pinch strength approximately 40% of normal.

CHAPTER 4

MEASUREMENT OF STIFFNESS

In 1954 Cobb, Warren, Thompson and Ciacco published a paper in which they reported that a review of the available literature revealed the growing impression that fibrositis was merely another manifestation of rheumatoid disease. This impression was based, at least in part, on the frequency with which morning stiffness appeared in both conditions. Their own impression was that morning stiffness was very often the earliest symptom of rheumatoid arthritis and was present in at least 85% of cases. They defined morning stiffness as 'stiffness of any degree in any group of joints or muscles that is noted on awakening in the morning and that passes off fairly rapidly as the individual becomes active'. They used the question 'Do you wake up with stiffness or aching in your joints or muscles?' to determine the presence of stiffness. They thus suggested an unquantified relationship between pain (aching) and stiffness and the possibility that joints and/or muscles could be the source of the symptom. They anticipated that the presence of morning stiffness may in future be used as a screening test for rheumatoid arthritis and in the differential

diagnosis of vague musculoskeletal problems. Their proposed diagnostic criteria for rheumatoid arthritis was published by Ropes, Bennett, Cobb, Jacox and Jessar in 1956 and revised by the Committee of the American Rheumatism Association in 1958 with morning stiffness heading the list of symptoms necessary for the diagnosis to be made.

Lansbury (1956) included morning stiffness and diurnal jelling, which he defined as 'morning stiffness in miniature, or stiffness occuring after rest during the day', in his system for recording systemic manifestations of rheumatoid arthritis. He recorded the time the patient got up in the morning and the time at which his stiffness wore off. He then regarded changes in the duration of morning stiffness as an objective measurement of disease activity and response to treatment, provided that the first dose and time of administration of asprin taken each morning was constant.

Duration of morning stiffness is still regarded as an important measure of disease activity. The Subcommittee for Criteria of Remission in Rheumatoid Arthritis of the American Rheumatism Association Diagnostic and Therapeutic Criteria Committee (Pinals, Masi and Larsen 1981) report it as being a

highly discriminating variable. In a study of 344 patients 96% of those with active disease had morning stiffness compared with only 18% of those in complete remission, but as Wright (1985) pointed out when he quoted the Kellgren and Lawrence population survey (1956), 'morning stiffness is a fickle symptom'. In 467 subjects between the ages of 55 and 64, 132 said they experienced stiffness in the morning when they were questioned at home. These subjects were brought to hospital and 118 on re-questioning said that they were stiff in the mornings. However, only 74 gave a positive answer on both occassions. This ambiguity could have been due to the confusion which still exists over the definition of stiffness. Although Thompson, Wright and Dowson (1978) proposed the definition 'stiffness is the resistance to passive motion at a joint throughout the normal range of movement in the usual functional plane', there is no evidence that physicians are agreed about what constitutes 'stiffness' and patients have been found to have a variety of definitions.

Rhind, Unsworth and Haslock (1987) questioned 100 patients with rheumatoid arthritis, all of whom claimed to be stiff, and found that although they had no difficulty assessing the severity of their

stiffness using various rating scales, their definition of the symptom was confused. Most of the patients first described their stiffness using pain related words such as hurts, sore, painful, while on further questioning, with the aid of a printed list of adjectives, they were equally likely to describe their stiffness in terms of pain or limited movement. Wright (1959 and 1985) suggested that patients may confuse muscle weakness or limited range of movement with joint stiffness.

Recognition of morning stiffness as a major symptom of rheumatoid arthritis and the need to measure it objectively led to the introduction of various devices designed to qualify and quantify the symptom.

Early work, using different devices, was done by Scott (1960), Wright and Johns (1960), and Hicklin, Wighton and Robinson (1967).

Scott used a spring loaded device to apply a fixed displacing force and measured the distance through which the index metacarpa-phalangeal (mcp) joint could be displaced from the neutral position into extension. He was able to show differences throughout the day in five patients with rheumatoid

arthritis. No comparison could be made between patients because of the difference in finger lengths.

Similar devices were later used by Loebl (1972) and by Wagner and Drescher (1984). Both these groups studied normal subjects and both found that women had greater displacements than men. Wagner and Drescher also found that the fifth finger was more mobile than the others in both flexion and extension. Rasker, Peters and Boon (1986) used a device called a 'Rigimeter' to impose a fixed displacement of 10 mm, imposed over two seconds, to the index, middle and ring fingers of patients with rheumatoid arthritis and normal control subjects to measure static resistance to extension. They found a positive correlation between the stiffness measured in patients and changes in the weather. The stiffness measurements increased in damp weather but were not affected by changes in humidity on the ward.

Ingpen and Hume Kendal (1968 and 1970) measured mcp joint stiffness using the device first described by Hicklin et al. This device consisted of a weighted lever attached to the index finger by a sheath. The finger was allowed to fall freely through a 10

degree arc and the time taken recorded either by use of a photoelectric cell (Hicklin et al.), or by using an electronic timer. They found that the fall time was remarkably constant, irrespective of age, size or sex in 150 clinically normal hands but was increased in patients with rheumatoid arthritis and there was a diurnal variation.

Wright and Johns used a pendulum driven arthrograph to study stiffness in the second mcp joint. The joint movement was produced by the pendulum oscillating a shaft which was attached to a lever which was taped to the index finger. They applied a maximum amplitude of motion of 30 degrees either side of the mid-point and varied the cycle frequency by altering the pendulum length. Torque was recorded by strain gauges bonded to the lever and angular displacement was recorded from a low torque potentiometer attached to the pendulum shaft. Hysteresis loops were presented on a dual beam cathode ray oscilloscope and were then photographed. These were then measured by planimetry or were cut out and weighed for comparison. Elastic stiffness was calculated as the slope of the line joining maximum and minimum values of the hysteresis loop. Study of three subjects, aged 4, 26 and 66 years, showed a progressive increase in this value and it

was concluded that elastic stiffness increases with age. They demonstrated an increase of elastic stiffness after cooling the hand and after venous occlusion and a decrease of elastic stiffness after heating the joints of two subjects. Two subjects with Ehlers-Danlos syndrome and seven with Marfans syndrome showed decreased joint stiffness and one patient with Parkinsonism and one with myotonia congenita showed increased stiffness. They studied electromyographic tracings recorded simultaneously with the arthrograph recording and found that neither active nor reflex muscle activity played a part in the stiffness measured at the joint.

Long, Thomas and Crochetiere (1964) were interested in muscle tone and spasticity rather than stiffness. They used an arthrograph similar to that of Wright and Johns to record hysteresis loops in six normal subjects while measuring EMG output from the muscles of the forearm. No muscular activity was seen and they concluded that resting muscle tone is not due to muscular activity but to properties inherent in the muscle.

Backlund and Tiselius (1967) used an arthrograph similar in principle to the one described by Wright and Johns to study objective measurement of

stiffness in relation to duration of morning stiffness and patients subjective assessment of stiffness severity. They also had five patients tested for I.Q. levels and personality factors and although their numbers were too small for any definite conclusions to be drawn, it is interesting to note that the three patients who had a close correlation between their objective and subjective measurements of stiffness scored higher in the I.Q. tests than did the two other patients.

Goddard, Dowson, Longfield and Wright (1969) and Such, Unsworth, Wright and Dowson (1975) then studied stiffness at the knee joint using an arthrograph which held the leg in the vertical position. They found a substantial difference in stiffness between male and female joints even when age, size of knee and size of thigh were taken into account. This arthrograph later proved to have problems attributable to the counterbalance system which was necessary to offset the weight of the leg but which distorted the torque displacement curve. Thompson, Wright and Dowson (1978) then designed an arthrograph which held the leg in an horizontal position to avoid any gravitational effect on the limb, but this was found to be uncomfortable for patients with joint disease and unacceptable to

female volunteer subjects. They were able to study four patients with joint disease and six male and six female healthy volunteers. In this study patients with rheumatoid arthritis were found to have lower stiffness values than normal while patients with osteoarthritis were stiffer than normal. Males showed greater energy dissipation and higher resistive torque at each angle of flexion than females.

In 1981 Unsworth, Bey and Haslock described a simplified type of finger arthrograph which moved the second mcp joint into flexion and extension in the horizontal plane. Unlike the earlier arthrographs it was not driven, the finger was moved into the desired position and resistive torque measured while the joint was stationary. The major difference between their work and that of previous researchers in this field was their recognition of the importance of establishing the equilibrium position of the joint. Earlier researchers had measured their subjects at given angles from the neutral position ie. the position in which the long axes of the proximal phalanx and the metacarpal are in line, but Unsworth et al. were able to show that the equilibrium position, or position of zero torque could vary from 16 - 44 degrees of flexion

(mean 33.2) depending on the subject and the immediate past history of joint movement. By identifing the equilibrium position for each subject and measuring resistive torque at defined angles of flexion and extension from that position, direct comparison could be made between subjects. They then designed a completely new, driven, arthrograph which also moved the second mcp joint into flexion and extension in the horizontal plane and linked it to an XYT recorder and subsequently to an analogue to digital converter and a microcomputer, thus providing instantaneous analysis of the hysteresis loops (Unsworth, Yung and Haslock 1982). Using this machine they demonstrated circadian variation of both dissipated energy and resistive torque in a small number of subjects (Yung, Unsworth and Haslock 1984). Investigation of the effects of physiotherapy suggested that a single application of wax, ice or exercise had no significant effect on joint stiffness, while a single application of ultrasonic therapy or short-wave diathermy produced a significant reduction in dissipated energy in patients with rheumatoid arthritis but had no effect on the joint stiffness of normal subjects (Yung, Unsworth and Haslock 1986).

Howe, Thompson and Wright (1985) described another

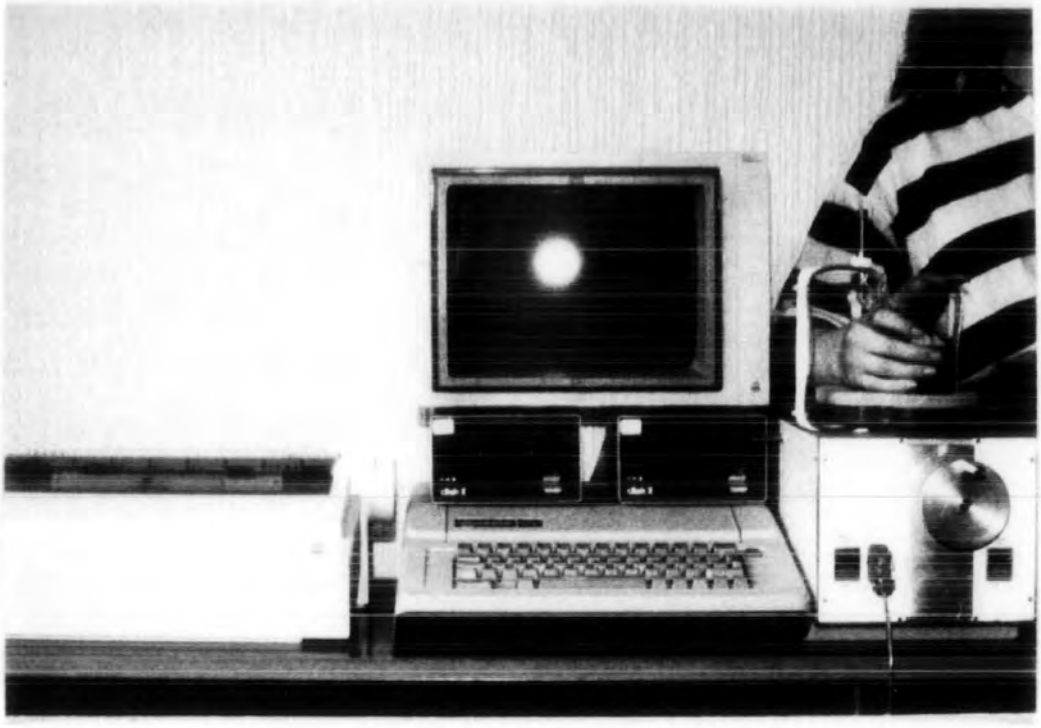
new type of arthrograph consisting of a drive system, limb support and torque transducer linked to a microcomputer. This machine also measured stiffness in the horizontal plane but differed from the Durham arthrograph by moving the joint in adduction / abduction instead of flexion / extension, thus making it possible to measure stiffness in the mcp joints of the index, middle and ring fingers of both hands. It could not be used with patients who had fixed flexion deformities of the interphalangeal joints or subluxation of the mcp joints with ulnar deviation. Those patients with subluxation and deformity of the wrist or with shoulder problems were also difficult to measure with this design of arthrograph.

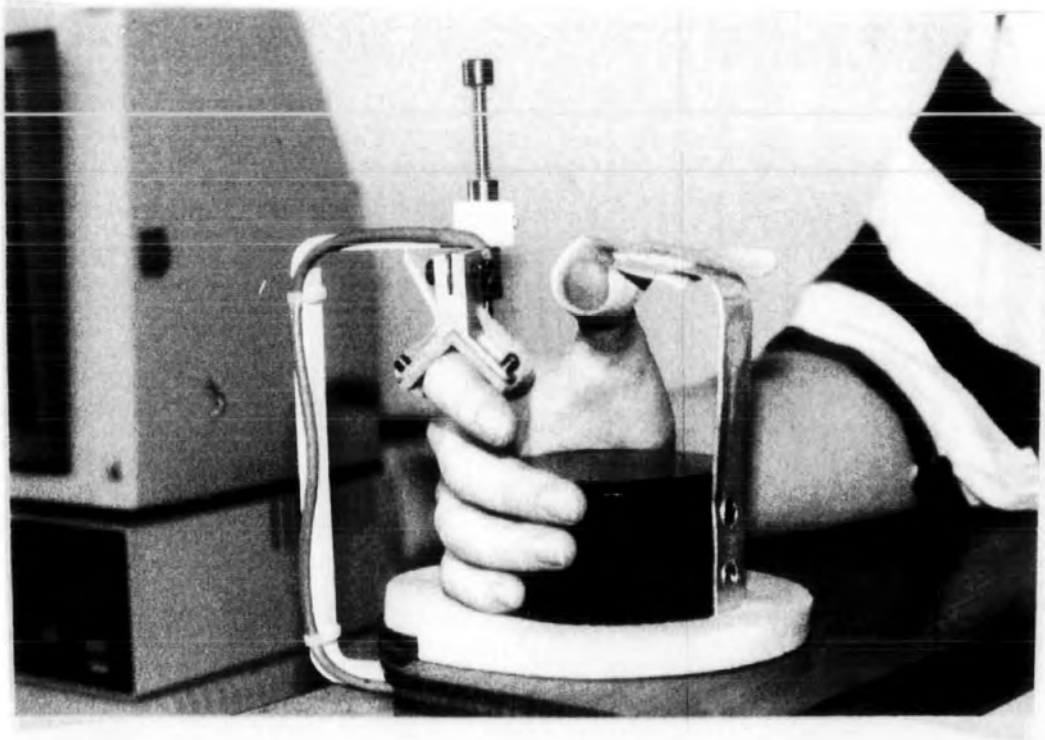
Helliwell (1987) used this machine to study stiffness of the third mcp joint and reported that most patients with rheumatoid arthritis had measured stiffness variables less than normal when the readings were adjusted to take account of the finger size, as did four patients with radiological joint destruction from symetrical polyarthritic psoriatic arthritis. He measured the size of the finger immediately distal to the web and found this measurement to be the predominating influence on the stiffness variables. Six patients with radiological

osteoarthrosis of their mcp joints, who also complained of pain and stiffness of these joints, were found to have increased stiffness values, as did three patients with mild scleroderma and eleven patients with ankylosing spondylitis. He did not find a correlation between subjective and objective stiffness measurements after inter-articular steroids or the application of ice. There was a correlation between the subjective and objective measurements after the application of wax and after administration of a single dose of Ibuprofen, but, as there was also a parallel change in the pain parameters this correlation was thought to be unreliable. He concluded that stiffness as measured by the arthrograph has little relevance to the stiffness experienced by the patient and suggested that there may be a limited range of movement in patients with rheumatoid arthritis which, although it may not change significantly over twenty four hours, may change with respect to the equilibrium position of the joint and it may be that patients perceive this change to be stiffness.

SECTION 2

EQUIPMENT AND METHODS





CHAPTER 5

THE DURHAM MICROCOMPUTER CONTROLLED ARTHROGRAPH

DESCRIPTION OF THE ARTHROGRAPH

The arthrograph was designed and built by Dr.A. Unsworth of the School of Engineering and Applied Science, University of Durham and subsequently modified J. Bromley.

The arthrograph consisted of a wooden arm rest, hand grip and thumb support, a drive assembly, potentiometer and a strain gauged transducer. It was interfaced to an Apple 11 E microcomputer via an A/D conversion card. The computer was equipped with twin disk drives and a printer (see plate 1).

The arm rest could be moved in any direction in the horizontal plane to enable the centre of rotation of the mcp joint of the index finger to be aligned with the centre of rotation of the arthrograph. Once alignment had been achieved the arm rest was locked into position by means of three clamps mounted on the main frame. A round wooden hand grip block and a thumb support with an adjustable 'Velcro' sling were mounted on the arm rest.

The transducer combined a torque measuring device and a finger clamp. The finger clamp consisted of a V block and an adjustable "Velcro" strap to secure the right index finger in position. The V block was screwed to the end of a stainless steel cantilever which in turn was secured to the central pivot of the arthrograph. Strain gauges were mounted on both sides of this cantilever to record the torque produced by the resistance to movement of the joint and associated soft tissues. The signal from the four strain gauges was amplified and fed to the Apple microcomputer where the analogue to digital conversion was carried out.

The drive assembly consisted of a synchronous motor and gear box unit connected to a scotch yoke mechanism. This mechanism oscillated the drive arm by means of a belt and pulley assembly. The drive arm had a fixed centre of rotation and the centre of rotation of the joint had to be aligned with this. The adjustable arm rest and a pointer attached to the transducer assisted in making sure this alignment was correct.

A precision potentiometer fixed to the central axis of rotation provided an analogue signal of the

angular rotation of the drive arm and mcp joint.

The Apple microcomputer was programmed in BASIC. A screen and keyboard allowed interaction with the computer and a printer provided hard copy of the results. The results could also be stored on floppy disks.

CALIBRATION OF THE ARTHROGRAPH

The arthrograph was designed to allow a range of motion from 20 degrees extension to 70 degrees flexion measured from the neutral position of the joint. The angular resolution was therefore limited to 0.35 degrees.

The amplitude of oscillation of the Scotch Yoke mechanism was set at 20 degrees (equivalent to 114 bits) and the gain was adjusted until the difference in digital readings at each end of the cycle was 114.

Torque range was calibrated by hanging known weights on a cord passing over a low friction pulley attached to the transducer at a known radius from the centre of rotation. Digital readings were then taken at each increment. Earlier work with the

arthrograph (Unsworth, Bey and Haslock 1981) had indicated that a suitable resolution was 0.001 Nm with range from 0.3 Nm to -0.3 Nm.

USE OF THE ARTHROGRAPH

The subject was seated in a chair with her right arm positioned comfortably on the adjustable arm rest of the arthrograph. The wrist was placed in the neutral position and the thumb was supported in the Velcro sling to allow free movement of the index finger into flexion. The index finger was positioned in the V block with the centre of rotation of the mcp joint aligned with the centre of rotation of the arthrograph and held in position by the Velcro strap. The other fingers rested lightly around the grip block (see plate 1).

Plastazote of various thickness was used to adjust the position of smaller hands in the arthrograph so that the joint was not displaced into adduction by the height of the transducer above the arm rest. Unfortunately the height of the transducer was not adjustable and this was found to be a problem, especially with very small and very large hands.

The subject was instructed to keep her hand relaxed

during the test and not to talk while the machine was in motion. It was noticed that contraction of the hand muscles often occured during speech and distorted the hysteresis loop. For those subjects who were able to remain relaxed during the test only one or two cycles were necessary.

Once the subject was correctly positioned, the drive was switched on and the finger rotated through 40 degrees, first into flexion and then into extension. A preliminary hysteresis loop was displayed on the screen for inspection and, if acceptable, the centre of the cycle, mean equilibrium position, energy dissipation, torque range, flexion, extension and mid-range slopes were automatically calculated. A copy of the hysteresis loop and the calculations was then printed out.

The test was usually completed within a few minutes except for those few patients who had difficulty remaining relaxed. The machine was acceptable to all patients, none complained of pain or discomfort during the tests and, as will be seen later, many were willing to return to the clinic for repeated tests.

No prior knowledge of computing was necessary to run

the system. It was easy to use after a short introductory period and was reasonably portable. Results could be stored on disk and printed as a hard copy for inclusion in the patients notes if desired.

ANALYSIS OF THE HYSTERESIS LOOP

Following the work of Unsworth et al. (1981) it had been decided to centre the oscillation on the equilibrium position of the joint. Helliwell (1987) and Bromley (thesis in preparation) have shown that small errors in position do not greatly affect the results.

Approximately three hundred pairs of readings were recorded during each test cycle. Using this data the centre of the cycle and the mean equilibrium position of the joint were calculated and the hysteresis loop plotted. These preliminary results were displayed on the screen. If the difference between the centre of cycle and mean equilibrium position was more than plus or minus five degrees then the position of the joint in relation to the centre of rotation of the arthrograph was checked and, if necessary, the centre of oscillation was moved further into either flexion or extension

until an acceptable level of coincidence was achieved.

When the preliminary results displayed on screen were accepted, the stiffness variables were calculated and printed.

Figure 1 shows a printout of a typical result and illustrates a hysteresis loop with calculated stiffness variables.

Figure 2 illustrates the calculation of the stiffness variables.

1. Peak to peak torque range was calculated from the maximum (A) and minimum (B) torque readings obtained and expressed in Newton meters (Nm).

2. The area of the hysteresis loop was calculated using the Trapezium Rule and expressed in Joules as energy dissipation.

3. The slopes of the hysteresis loop at the flexion, extension and mid-range positions were calculated (see figure 2) and expressed in Nm/degrees.

FIGURE 1.

RESULTS

No. of points taken = 298 Mean eq.position = 36.1 deg

Centre of cycle = 32.9 deg

Torque range (peak to peak) = .1496 NM

Energy dissipation = .02300292 Joules

SLOPES UNITS NM/DEG

Flexion = 6.815E-03

Extension = 4.154E-03

Mid position = 1.520E-03

HYSTERESIS LOOP Horizontal scale ; 1 division = 10 deg

Vertical scale ; 1 division = 0.05 NM

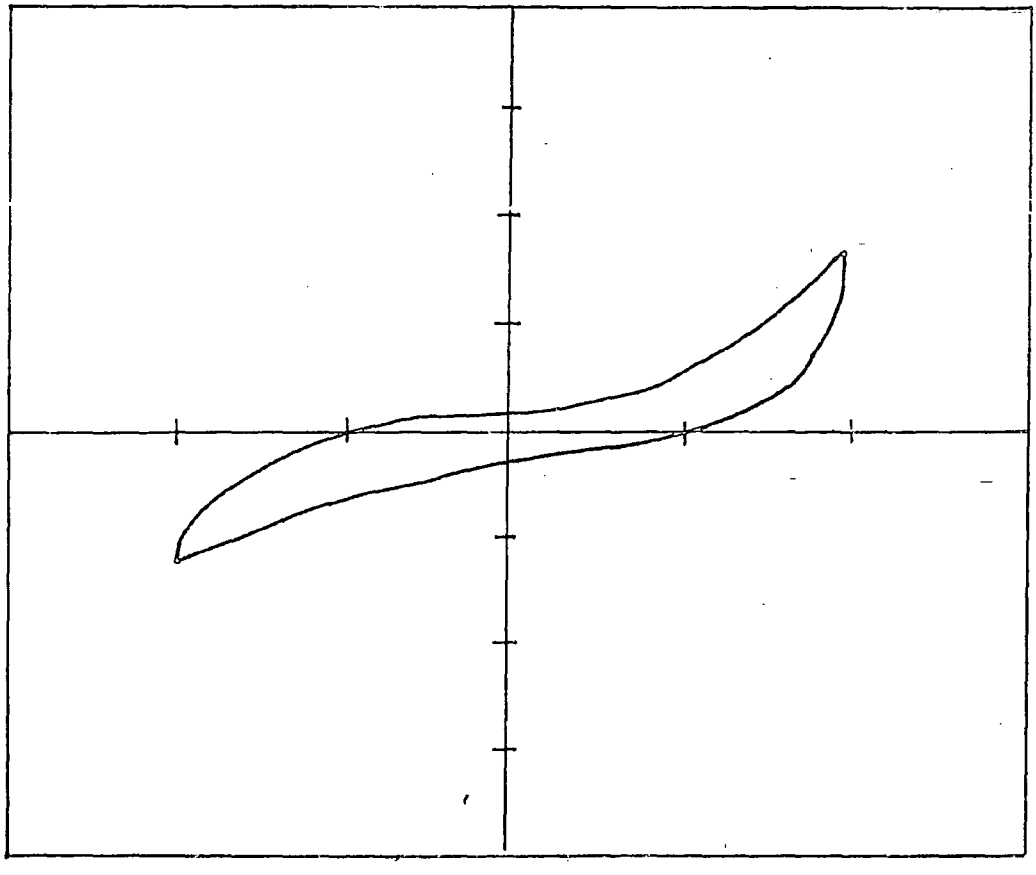
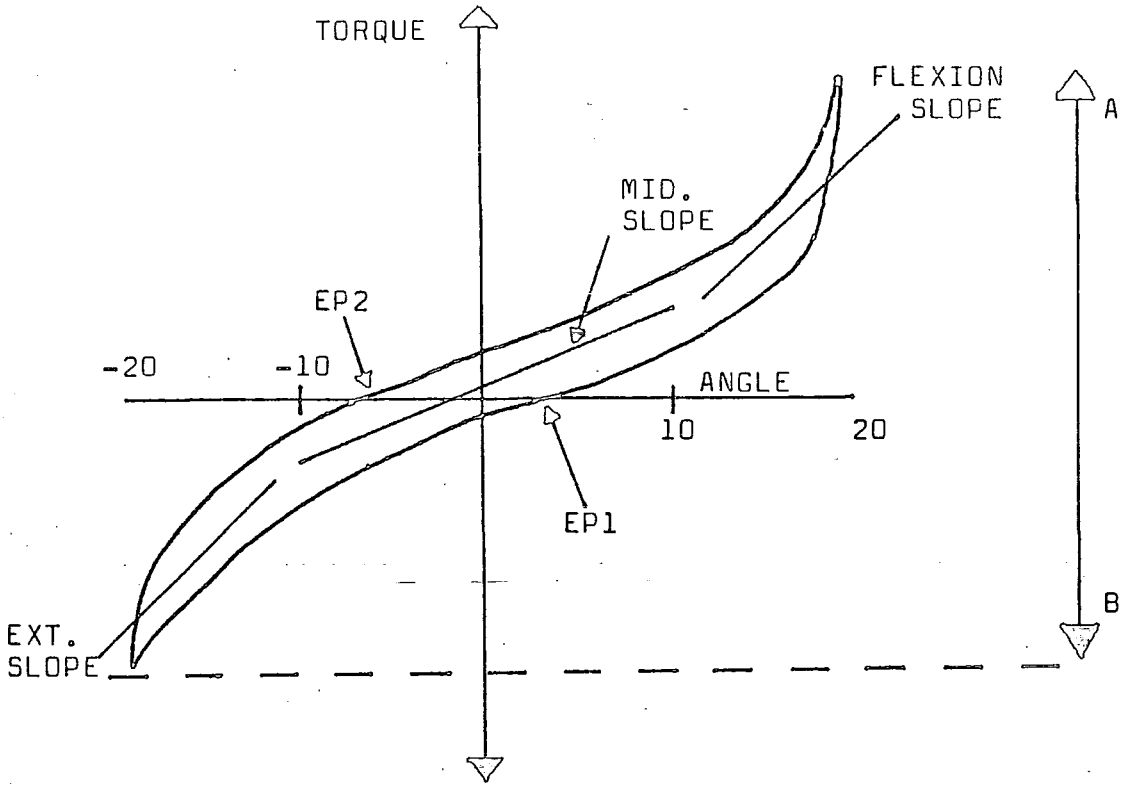


FIGURE 2.



DEFINITIONS

Torque : positive when resisting flexion

Angle : shown positive in flexion with reference to the cycle centre

Energy dissipation : the area of the hysteresis loop

Mean equilibrium position : the mean of EP1 and EP2

Torque range : the peak to peak difference in torque, A to B

Flexion slope : best straight line through the last ten degrees flexion

Extension slope : best straight line through last ten degrees extension

Mid slope : best straight line through the central twenty degrees.

CHAPTER 6

INSTRUMENTS TO MEASURE SIZE

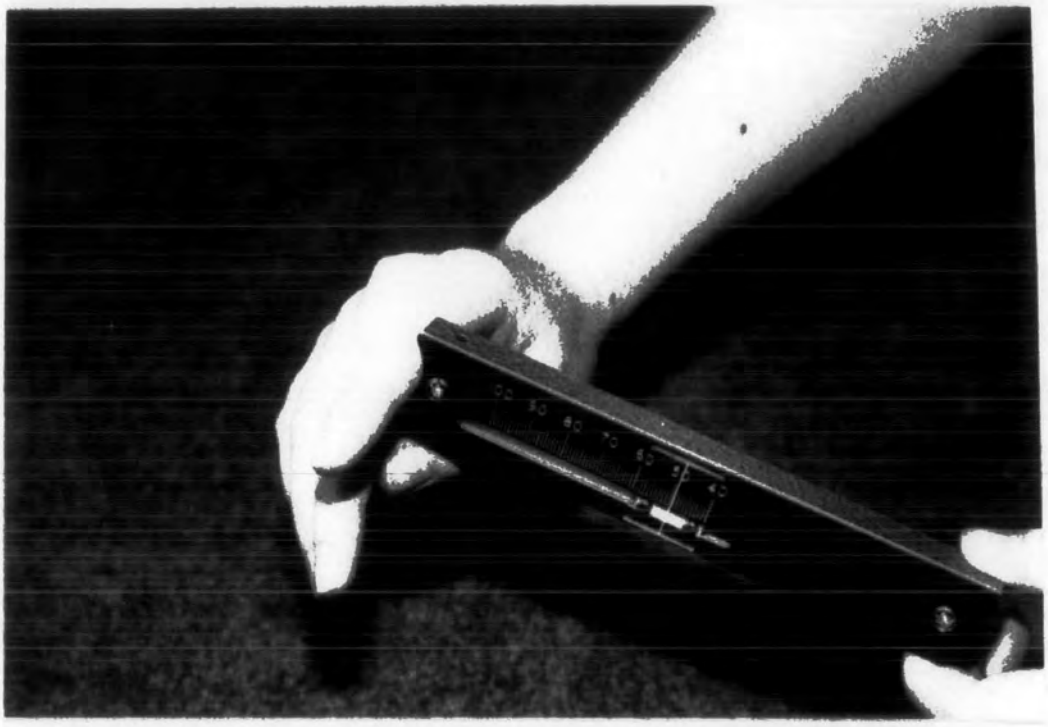
1. THE ARTHROCIRCOMETER

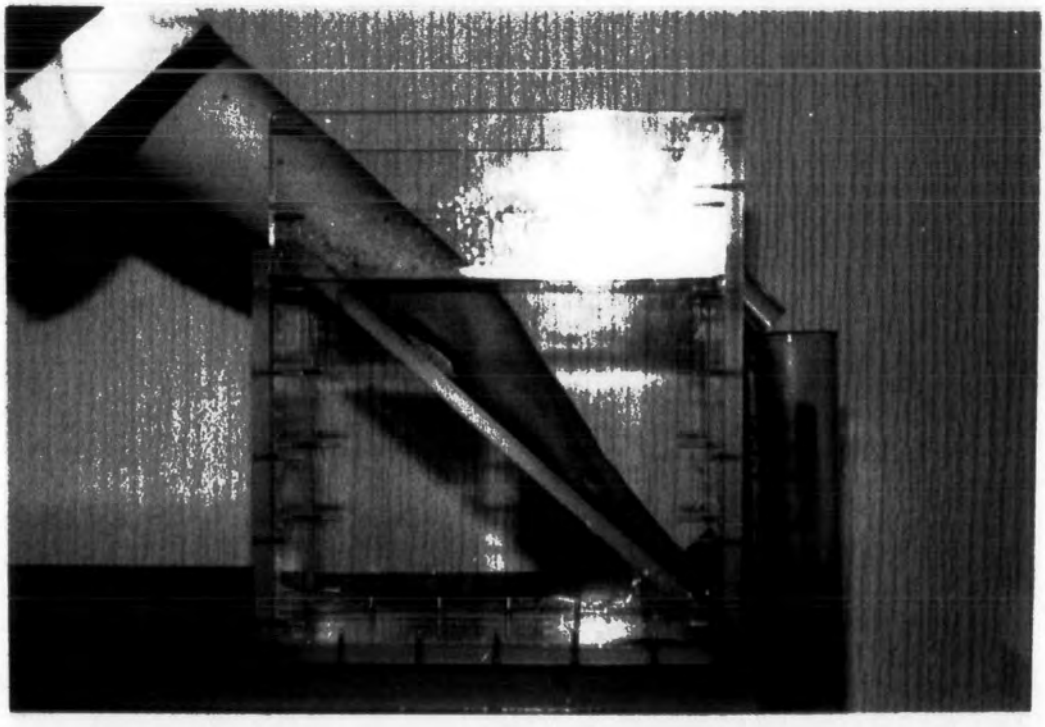
The arthrocircometers used in this study were manufactured by the Medical Faculty Workshops, University of Nottingham. The instrument consisted of a metal body 16 cm long, 2.5 cm wide and 1.4 cm deep marked with a linear scale from 40 mm to 100 mm in 1 mm increments. It had an external sliding marker attached to an internal spring. The spring was also attached to a flexible polyethylene strap which formed the loop which was placed around the joint to be measured (see plate 2).

CALIBRATION OF THE ARTHROCIRCOMETER

Prolonged use of the arthrocircometer may cause stretching of the polyethylene strap and weakening of the spring leading to error in measurement of the joints. It was therefore necessary to check the calibration of the instrument at regular intervals using rods of known circumference. During this study two matched instruments were used and neither

PLATE 2





had to be discarded.

2. THE HAND-VOLUME TANK

A tank measuring 24 x 17 x 28.5 cm. was constructed of 1 cm. perspex. An over-flow tube, 2 cm. in diameter, was inserted 6.5 cm. below the upper edge of one end of the tank. A sheet of perspex was fitted diagonially across the tank to form a hand rest and a triangular piece was fixed at the bottom of the hand rest to provide a 'stop' (see plate 2).

USE OF THE HAND-VOLUME TANK

The tank was placed on a low table and filled with tepid water to a level above the over-flow tube. The excess water was allowed to flow out. The subject was seated on a straight backed chair positioned so that the right hand could be placed in the tank comfortably. When the water level was static the subject was asked to slide her hand slowly down the hand rest until her middle finger came into contact with the 'stop'. The wrist was centered between two markers and the water displaced through the over-flow tube was collected in a graduated measuring cylinder. The hand was kept immersed for four minutes, timed on a stop watch.

This method of measuring size of the hand is inexpensive and simple. It was acceptable to all the subjects included in this study and, as long as they were seated comfortably, none found it a problem to keep the hand in position for four minutes. Patients with flexion deformity of the mcp or pip joints and those with ulnar deviation required more careful positioning of the hand to ensure reproducibility.

CHAPTER 7

THE DYNAMOMETER

The dynamometer used in this study consisted of a cloth covered rubber bag attached, by means of two rubber tubes, to a rubber bulb with a screw valve and a conventional sphygmomanometer pressure gauge. The pressure gauge was marked from 20 to 300 mm Hg.

USE OF THE DYNAMOMETER

The subject was seated on a straight backed chair with no arm rests. She was instructed to hold her arm slightly away from her body with her elbow at approximately 90 degrees flexion and her palm uppermost. The rubber bag of the dynamometer was inflated to 30 mm Hg and placed in the subject's hand. She was encouraged to squeeze the bag as hard as possible and the maximum pressure produced was recorded. The reading on the pressure gauge was not visible to the subject during the test. The procedure was repeated with alternate hands until six measurements had been made. The mean of three readings for each hand was recorded.

SECTION 3

RESULTS

CHAPTER 8

DESCRIPTION AND ANALYSIS OF SINGLE MEASUREMENT DATA OBTAINED FROM PATIENTS AND HEALTHY CONTROL SUBJECTS

The aim of this part of the study was to compare the objective stiffness variables, measured by the Durham arthrograph, with grip strength, hand volume and pip joint sizes of healthy women and women with rheumatoid arthritis. In the patient group, two biochemical assessments of disease activity and subjective assessments of pain and stiffness were also compared with the arthrographic measurements of stiffness.

One hundred and eighty five subjects, aged between 15 and 76 years, were studied. Eighty five of these women had previously been diagnosed as suffering from rheumatoid arthritis and at the time of the study were attending a Rheumatology Out-Patient Clinic for treatment. The other one hundred women had no signs or history of rheumatoid disease and reported themselves as being completely healthy at the time of the study.

All subjects were studied between the hours of 10 am and 4 pm when stiffness and swelling is at a minimum and grip strength at a maximum.

Table 8.1 lists the details recorded and variables measured for each subject.

Arthrographic measurements of stiffness were made as described in chapter 5. Hand volume and pip joint size measurements were made as described in chapter 6. Grip strength measurements were made as described in chapter 7. In addition to these objective measurements the patients were asked to assess and record the severity of their pain and stiffness using 0 - 10 numerical rating scales (as described in chapter 1). Joint tenderness was assessed using the Articular Index (described in chapter 1), and tenderness in the right hand was assessed using a modified articular index. Duration of early morning stiffness was recorded. Patient's plasma viscosity and haemoglobin were also recorded.

The data were subjected to statistical analysis using SPSS-X software.

TABLE 8.1

CLINICAL DETAILS RECORDED IN ALL SUBJECTS

Date of birth.	Age.
Date of Last Menstrual Period.	
Current drug treatment.	
Volume of right hand.	
Size of proximal interphalangeal joints	1. Right hand 2. Left hand.
Grip strength	1. Right hand 2. Left hand.
Arthrographic variables	1. Mean equilibrium position 2. Torque range 3. Energy dissipation 4. Flexion slope 5. Extension slope 6. Mid position slope

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ADDITIONAL DETAILS RECORDED IN PATIENTS

Articular index

Modified articular index - right hand

Severity of pain at time of interview.

Severity of stiffness at time of interview.

Severity of early morning pain.

Severity of early morning stiffness.

Duration of early morning stiffness.

Plasma viscosity.

Haemoglobin.

TABLE 8.2 DESCRIPTIVE STATISTICS OF THE ARTHROGRAPHIC VARIABLES

	n	MEAN	RANGE	STD DEV	MANN-WHITNEY U TEST	
					Z	P
EQUILIBRIUM	100	28.89	33.2	7.554	-0.2204	.8255
POSITION (DEG)	85	29.0	31.4	7.135		
TORQUE RANGE	100	6.45	9.61	2.163	-0.8064	.4200
(NM E-02))	85	6.60	20.02	3.014		
DISSIPATED	100	1.12	2.47	.381	-2.5842	.0098
ENERGY (E-02)	85	1.07	7.37	.808		
FLEXION SLOPE	100	2.108	4.99	1.027	-0.6805	.4962
(NM./DEG E-03)	85	2.128	10.46	1.604		
EXTENSION SLOPE	100	1.87	3.31	.681	-1.7763	.0763
(NM./DEG E-03)	85	2.22	6.10	1.008		
MID SLOPE	100	.936	1.552	.319	-0.8527	.3938
(NM./DEG E-03)	85	.905	2.128	.373		

TABLE 8.3 CORRELATION COEFFICIENTS OF THE ARTHROGRAPHIC VARIABLES AFTER Z SCORE VARIABLE TRANSFORMATION

	AGE	EQUILIBRIUM POSITION	TORQUE RANGE	DISSIPATED ENERGY	FLEXION SLOPE	EXTENSION SLOPE
EQUILIBRIUM POSITION	.0883 P=.116					
TORQUE RANGE	-.0105 P=.443	.1418 P=.027				
DISSIPATED ENERGY	.0301 P=.342	-.0390 P=.299	.4278 P<.001			
FLEXION SLOPE	-.0487 P=.255	.1499 P=.021	.8930 P<.001	.3100 P<.001		
EXTENSION SLOPE	.2231 P=.001	-.0715 P=.167	.6579 P<.001	.2957 P<.001	.3499 P<.001	
MID SLOPE	-.0812 P=.136	.1119 P=.065	.8652 P<.001	.4559 P<.001	.6743 P<.001	.6042 P<.001

n = 185 PATIENTS AND HEALTHY CONTROL SUBJECTS

DESCRIPTIVE STATISTICS OF THE ARTHROGRAPHIC VARIABLES

Table 8.2 presents the mean, range, standard deviation, Mann-Whitney z value and two tailed probability of the arthrographic stiffness variables of the two groups of subjects.

Table 8.3 presents the coefficients of correlation and P values for the combined data after the variables had been expressed in standardized (Z-score) form.

EQUILIBRIUM POSITION

The mean values and standard deviations for the two groups were very close (mean 28.89 degrees for control subjects and 29.0 degrees for patients, standard deviation 7.554 and 7.135 respectively). The results show no significant difference between the two groups ($z = -0.2204$, $P = .825$). There were weak, statistically significant, correlations with torque range and flexion slope but no significant correlation with dissipated energy, extension slope, mid-position slope or age.

TORQUE RANGE

The mean peak to peak torque range was similar in the two groups of subjects studied (6.45E-02 for control subjects and 6.6E-02 for patients). The patient group had a wider range of values and a larger standard deviation. The wider range of values was due to four patients who had extreme values. However the two groups were not significantly different ($z = -0.8064$ $P = .420$). Mean torque range had no significant correlation with age. It had a weak but statistically significant correlation with equilibrium position ($r = .1418$ $P = .027$) and dissipated energy ($r = .4278$ $P < .001$), a moderate correlation with extension slope ($r = .6579$ $P < .001$) and strong correlations with flexion and mid-position slopes.

DISSIPATED ENERGY

The mean dissipated energy was similar in the two groups (1.12E-02 for the control group and 1.07E-02 for the patient group). The wider range of values in the patient group was the result of three patients with extreme values. The results show a significant difference between the two groups ($z = -2.5842$

P = .009). There was no significant correlation with age or equilibrium position. There were weak but statistically significant correlations with torque range (r = .4278 P <.001), flexion slope (r = .310 P <.001) extension slope (r = .2957 P<.001) and mid-position slope (r = .4559 P <.001).

FLEXION SLOPE

The mean slope of the hysteresis loop between 10 and 20 degress into flexion from the equilibrium position (Flexion Slope) was similar in the two groups (2.108E-03 for the control group and 2.128E-03 for the patient group). The patient group had a wider range of values due to two patients with extreme values. The two groups were not significantly different (z = -0.6805 P = .496). There was no significant correlation with age. There were weak, statistically significant, correlations with equilibrium position (r = .1499 P = .021), dissipated energy (r = .310 P<.001) and extension slope (r = .3499 P<.001), moderate correlation with mid-position slope (r = .6743 P<.001) and a strong correlation with torque range.

EXTENSION SLOPE

The mean slope of the hysteresis loop between 10 and 20 degrees into extension from the equilibrium position (Extension Slope) was 1.87E-03 for the control group with standard deviation of .068, and 2.22E-03 for the patient group with standard deviation .109. Four patients had extreme values. The results show that the two groups were not significantly different ($z = -1.7763$ $P = .076$). There was a weak but statistically significant positive correlation with age ($r = .2231$ $P<.001$) in the pooled data. When the groups were analysed separately there was no significant correlation with age in the control group. There was no significant correlation between extension slope and equilibrium position. There were weak statistically significant correlations with dissipated energy ($r = .2957$ $P<.001$) and flexion slope ($r = .3499$ $P<.001$) and moderate correlations with torque range ($r = .6579$ $P<.001$), and extension slope ($r = .6042$ $P<.001$).

MID POSITION SLOPE

The mean slope of the hysteresis loop between 10 degrees into flexion and 10 degrees into extension

was .936E-03 for the control group with standard deviation of .319 and .905E-03 for the patient group with standard deviation .373. There was one patient with an extremely high value and one with an extremely low value. The two groups were not significantly different ($z = -0.8527$ $P = .393$). There was no significant correlation with age or equilibrium position. There was a weak but statistically significant correlation with dissipated energy ($r = .4559$ $P<.001$) and moderate correlations with flexion slope ($r = .6743$ $P<.001$) and extension slope ($r = .6042$ $P<.001$) and a strong correlation with torque range.

DESCRIPTIVE STATISTICS OF THE CLINICAL VARIABLES

Table 8.4 presents the mean, range, standard deviation, Mann-Whitney z value and two tailed probability of the clinical variables measured in the two groups.

Table 8.5 presents the coefficients of correlation between patients' clinical and biochemical variables after all the variables had been expressed in standardized (z-score form).

Table 8.6 presents the coefficients of correlation

TABLE 8.4 DESCRIPTIVE STATISTICS OF THE CLINICAL VARIABLES

	n	MEAN	RANGE	ST.DEV.	MANN-WHITNEY U TEST Z	P
RIGHT HAND VOLUME (mls)	100	330.28	194.0	36.105	-2.9495	.0032
	85	347.44	193.0	42.919		
PIP JOINTS RIGHT HAND (mms)	100	257.78	59.0	12.532	-4.5942	<.0001
	85	268.13	76.0	15.584		
GRIP STRENGTH RIGHT HAND	100	301.58	341.0	73.475	-8.2248	<.0001
	85	141.49	338.0	76.065		

n 100 = CONTROL SUBJECTS

n 85 = PATIENTS

TABLE 8.5

CORRELATION COEFFICIENTS OF THE CLINICAL VARIABLES IN PATIENTS AFTER Z SCORE VARIABLE TRANSFORMATION

RIGHT HAND VOLUME	.2250 P=.019				
RIGHT HAND PIP SIZE	.3679 P<.001	.5630 P<.001			
RIGHT HAND GRIP STRENGTH	-.3125 P=.002	-.1145 P=.148	-.1914 P=.040		
PLASMA VISCOSITY	.3717 P<.001	.1916 P=.045	.3246 P=.002	-.2610 P=.010	
HAEMOGLOBIN	-.0138 P=.452	-.1837 P=.053	-.4143 P<.001	.0775 P=.249	-.1621 P=.077
	AGE	RIGHT HAND VOLUME	RIGHT HAND PIP SIZE	RIGHT HAND GRIP STRENGTH	PLASMA VISCOSITY

N = 79 FOR CORRELATIONS INVOLVING PLASMA VISCOSITY AND HAEMOGLOBIN

N = 85 FOR ALL OTHER CORRELATIONS

TABLE 8.6 CORRELATION COEFFICIENTS OF THE CLINICAL VARIABLES IN THE HEALTHY CONTROL GROUP

RIGHT HAND VOLUME	.3227 P=.001		
RIGHT HAND PIP SIZE	.5132 P<.001	.7151 P<.001	
RIGHT HAND GRIP STRENGTH	-.2994 P=.017	-.0865 P=.275	-.0610 P=.337
	AGE	RIGHT HAND VOLUME	RIGHT HAND PIP SIZE

N = 100

between the clinical variables of the control group.

RIGHT HAND VOLUME

Right Hand Volume had a similar range in the two groups (253 - 447 mls in the normal group, 259 - 452 mls in the patient group) but the mean and standard deviation were higher in the patient group. The Mann-Whitney test showed a statistically significant difference between the two groups ($z = -2.9495$, $P = .0032$). Both groups showed a weak but statistically significant positive correlation with age. In order to ensure that the statistical difference between the two groups was not due to difference between ages, a subgroup of 120 age matched subjects (60 patients, 60 controls) was studied. The Mann-Whitney test showed a statistically significant difference between the patients and control subjects in the subgroup ($z = -3.0254$ $P = .0025$)

RIGHT HAND PIP JOINT SIZE

Proximal interphalangeal joint size was found to have a weak but statistically significant positive correlation with age in both groups of subjects. The mean, range and standard deviation was greater in the patient group and the Mann-Whitney test

showed a significant difference between the groups ($z = 4.5942$ $P<.0001$). This difference was maintained when the age matched subgroup was studied.

Both patient and control group showed a statistically significant correlation between right hand volume and pip joint size (patients $r = .5630$, $P < .001$; controls $r = .7151$ $P<.001$).

In the patient group, pip joint size had weak but statistically significant correlation with plasma viscosity ($r = .3246$ $P=.002$) and haemoglobin estimation ($r = -.4143$ $P<.001$).

RIGHT HAND GRIP STRENGTH

Grip strength was found to have a weak, but statistically significant,negative correlation with age in both groups. This association was stronger in the patient group. Mean grip strength in the patient group (141.49) was less than 50% that of the normal group (301.58). The Mann-Whitney test showed a statistically significant difference between the two groups ($z = -8.2248$ $P<.0001$). This difference was maintained when the age matched subgroup was studied.

TABLE 8.7

CORRELATION COEFFICIENTS BETWEEN THE ARTHROGRAPHIC VARIABLES AND THE CLINICAL VARIABLES IN PATIENTS

AFTER Z SCORE VARIABLE TRANSFORMATION

EQUILIBRIUM POSITION	.1520 P=.082	.0293 P=.395	-.3125 P=.002	.0681 P=.275	.1256 P=.135
TORQUE RANGE	.2277 P=.018	.3667 P<.001	-.1099 P=.158	.0145 P=.449	-.1180 P=.150
ENERGY DISSIPATION	.1286 P=.120	.2568 P=.009	-.0760 P=.245	.0107 P=.463	-.0816 P=.237
FLEXION SLOPE	.2168 P=.023	.3284 P=.001	-.0881 P=.211	.0101 P=.465	-.0365 P=.375
EXTENSION SLOPE	.1490 P=.087	.3417 P=.001	-.1561 P=.077	.0756 P=.254	-.2145 P=.029
MID-POSITION SLOPE	.1818 P=.048	.2731 P=.006	-.0602 P=.292	-.0983 P=.194	-.1386 P=.112
	RIGHT HAND VOLUME	RIGHT HAND PIP SIZE	RIGHT HAND GRIP STRENGTH	PLASMA VISCOSITY	HAEMOGLOBIN

N = 79 FOR CORRELATIONS INVOLVING PLASMA VISCOSITY AND HAEMOGLOBIN

N = 85 FOR ALL OTHER CORRELATIONS

TABLE 8.8

CORRELATION COEFFICIENTS BETWEEN THE ARTHROGRAPHIC VARIABLES AND THE CLINICAL VARIABLES IN THE CONTROL GROUP

AFTER Z SCORE VARIABLE TRANSFORMATION

	RIGHT HAND VOLUME	RIGHT HAND PIP SIZE	RIGHT HAND GRIP STRENGTH
EQUILIBRIUM POSITION	-.0079 P=.469	.0280 P=.391	-.1481 P=.152
TORQUE RANGE	.2060 P=.020	.2365 P=.009	-.1223 P=.199
ENERGY DISSIPATION	.2478 P=.006	.3502 P<.001	-.1975 P=.085
FLEXION SLOPE	.0957 P=.172	.0703 P=.243	.1305 P=.183
EXTENSION SLOPE	.3376 P<.001	.4267 P<.001	-.1391 P=.168
MID-POSITION SLOPE	.3112 P=.001	.3355 P<.001	-.1004 P=.244

N = 100

Grip strength of the right hand showed no significant correlation with right hand volume or pip joint size in either group.

CORRELATION BETWEEN THE CLINICAL AND ARTHROGRAPHIC VARIABLES

Table 8.7 presents a correlation matrix of the clinical, and biochemical variables with the arthrographic variables for the patient group.

Table 8.8 presents a correlation matrix of the clinical and arthrographic variables for the control group.

In the patient group, there was no significant correlation between plasma viscosity and any of the arthrographic variables. Haemoglobin had a weak correlation with extension slope, significant at $P<.05$ level.

Right hand grip strength had a significant correlation with equilibrium position in the control group only. There was no other significant correlation between grip strength and the arthrographic variables in either group.

Right hand pip joint size had weak but statistically significant correlations with all the arthrographic variables except equilibrium position in the control group and all except equilibrium position and flexion slope in the patient group.

Right hand volume had weak but statistically significant correlations with torque range and mid-position slope in both groups, energy dissipation and extension slope in the control group and flexion slope in the patient group.

DESCRIPTIVE STATISTICS OF THE SUBJECTIVE VARIABLES

Table 8.9 presents the mean, range and standard deviation of the articular index, modified articular index of the right hand (right hand index), early morning stiffness, stiffness at the time of interview, early morning pain, pain at the time of interview and duration of early morning stiffness.

Table 8.10 presents the correlation coefficients between the arthrographic variables and the subjective pain and stiffness variables after they had all been expressed in standardized (z-score) form. This matrix shows that there were weak

correlations, which reached statistical significance at the $P<.05$ level, between extension slope and articular index, stiffness at the time of interview and duration of morning stiffness, and between torque range and duration of morning stiffness.

Table 8.11 presents the correlation coefficients between the objective clinical variables and the subjective variables. This matrix shows right hand volume had no correlation with the subjective pain and stiffness variables. Right hand pip joint size had a weak but statistically significant correlation with right hand index ($r = .2064$ $P = .029$). Right hand grip strength had statistically significant correlations with all the subjective variables. Plasma viscosity had statistically significant correlations with articular index and duration of early morning stiffness. Haemoglobin had statistically significant correlations with severity and duration of early morning stiffness and with severity of early morning pain.

Table 8.12 presents the mean, range and standard deviation of plasma viscosity and haemoglobin estimation in 79 patients.

TABLE 8.9 DESCRIPTIVE STATISTICS OF THE SUBJECTIVE VARIABLES

	MEAN	RANGE	STD DEV
ARTICULAR INDEX	12.44	41.0	9.728
ARTICULAR INDEX RIGHT HAND	2.68	15.0	3.392
EARLY MORNING STIFFNESS	3.99	10.0	2.954
STIFFNESS AT INTERVIEW	2.69	9.0	2.721
EARLY MORNING PAIN	3.89	10.0	2.911
PAIN AT INTERVIEW	3.13	10.0	2.558
DURATION MORNING STIFFNESS	47.38	240.0	54.786

n = 85

TABLE 8.10 CORRELATION COEFFICIENTS BETWEEN THE ARTHROGRAPHIC VARIABLES AND THE SUBJECTIVE VARIABLES IN PATIENTS

AFTER Z-SCORE VARIABLE TRANSFORMATION

	EQUILIBRIUM POSITION	TORQUE RANGE	ENERGY DISS.	FLEXION SLOPE	EXTENSION SLOPE	MID-POS SLOPE
ARTICULAR INDEX	.1331 P=.112	.1243 P=.129	-.0401 P=.358	.0946 P=.195	.1882 P=.042	.0760 P=.245
RIGHT HAND INDEX	.0799 P=.234	.0713 P=.258	-.0739 P=.251	.0316 P=.387	.1706 P=.059	.0331 P=.382
EARLY MORNING STIFFNESS	-.0003 P=.499	.1604 P=.071	-.0139 P=.450	.0647 P=.278	.1770 P=.053	.1261 P=.125
STIFFNESS AT INTERVIEW	-.1265 P=.124	.1710 P=.059	.0560 P=.305	.0338 P=.379	.2519 P=.010	.1639 P=.067
EARLY MORNING PAIN	-.0087 P=.469	-.0069 P=.475	-.1405 P=.100	-.0010 P=.496	-.0574 P=.301	-.1022 P=.176
PAIN AT INTERVIEW	-.0460 P=.338	.0747 P=.249	.0212 P=.423	.0313 P=.388	.0839 P=.223	.0187 P=.433
DURATION OF STIFFNESS	-.0339 P=.380	.2406 P=.014	-.0627 P=.286	.2007 P=.034	.2512 P=.011	.1163 P=.146

N = 85

TABLE 8.11

CORRELATION COEFFICIENTS BETWEEN THE SUBJECTIVE VARIABLES AND THE CLINICAL VARIABLES IN PATIENTS

AFTER Z-SCORE VARIABLE TRANSFORMATION

	RIGHT HAND VOLUME	RIGHT HAND PIP SIZE	RIGHT HAND GRIP STRENGTH	PLASMA VISCOSITY	HAEMOGLOBIN
ARTICULAR INDEX	.1098 P=.158	.1573 P=.075	-.5689 P<.001	.2541 P=.012	.0026 P=.491
RIGHT HAND INDEX	.0891 P=.209	.2064 P=.029	-.4338 P<.001	.1523 P=.090	.0777 P=.248
EARLY MORNING STIFFNESS	.1438 P=.095	.1399 P=.101	-.4085 P<.001	.0432 P=.353	-.2317 P=.020
STIFFNESS AT INTERVIEW	-.0541 P=.311	-.0403 P=.357	-.2548 P=.009	.0669 P=.279	-.1057 P=.177
EARLY MORNING PAIN	.0538 P=.312	.1262 P=.125	-.3354 P=.001	.1090 P=.170	-.2142 P=.029
PAIN AT INTERVIEW	.0520 P=.318	.1620 P=.069	-.3460 P=.001	.0752 P=.255	-.1204 P=.145
DURATION OF STIFFNESS	.1073 P=.166	.1397 P=.102	-.2431 P=.013	.2488 P=.014	-.2086 P=.033

TABLE 8.12 DESCRIPTIVE STATISTICS OF THE BIOCHEMICAL VARIABLES

	MEAN	RANGE	STD DEV
PLASMA VISCOSITY	1.69	.64	.126
HAEMOGLOBIN	12.29	7.70	1.321

r = -.1621 P = .077

N = 79 PATIENTS

DISCUSSION

In this study age was found not to be a significant factor in increasing stiffness although there was a significant relationship between age and grip strength, pip joint circumference and hand volume. The results show a clear relationship between both hand volume and pip joint circumference and stiffness of the index mcp joint, in patients with rheumatoid arthritis and healthy subjects. Pip joint circumference was a better discriminator between the two groups than hand volume.

The relationships between sex, age, size and stiffness have been reported by a number of previous investigators. Loebl (1972) showed that women had a greater range of movement than men but could find no relationship between range of movement and age in either sex. He studied a total of 228 subjects. Such et al (1975) studied 70 subjects. They measured stiffness of the knee joint and found an increase in dissipated energy with age but no increase in torque range with age. Both dissipated energy and torque range increased with circumference of thigh and knee and were higher in males than females. They did not report whether circumference of knee and thigh were related to age but did

mention that some subjects in the 6th decade exhibited the same dissipated energy as some in the 2nd decade. A larger sample size may have increased the incidence of similarity in dissipated energy and so decreased the relationship with age. Thompson (1978), in a study of 39 subjects, was unable to show an increase in knee stiffness with age. Howe et al (1985) and Helliwell (1987) found that finger circumference, measured close to the web, was the single dominating influence on stiffness of the mcp joint of the middle finger. Helliwell also showed that the difference in stiffness parameters between male and female subjects could be explained solely by the difference in finger size. Unsworth et al (1981) showed a relationship bewteen wrist circumference and stiffness of the mcp joint of the index finger.

The correlation between age and pip joint circumference in this study and between age and finger size as measured by Helliwell (1987) is difficult to explain. The age range of subjects in this study was 15 to 76 years and in Helliwell's study 11 to 76 years. A longitudinal study would be necessary to determine whether the joint circumference of individuals continues to increase after maturity or whether there is a trend towards

thinner fingers in successive generations.

Grip strength was found to be the variable which best discriminated between the two groups. It had no significant correlation with any of the objective stiffness parameters in either group. In the patient group it was found to have a closer relationship with subjective pain than with subjective stiffness. In all age groups, patients were significantly weaker than the control subjects. Maximum grip strength in the patient group was approximately 47% that of the control group. This is less difference than that reported by Helliwell (1987) and is probably a reflection of disease activity at the time of measurement. The patients in his study were all in-patients and, presumably, all in an active phase of the disease, the patients in the present study were all out-patients. Jones et al (1985) studied the grip strength of twenty healthy control subjects and thirty eight patients with rheumatoid arthritis. They reported that the average grip strength of patients was less than one third that of the control subjects. When they analysed the results from the in-patients and out-patients separately, they found that the average grip strength of the in-patients was approximately one fifth of the value for the control subjects

while that of the out-patients was only slightly less than normal.

Unfortunately, because of design differences in the arthrographs and measurement of stiffness in different planes, it was impossible to make direct comparison between most of the stiffness parameters measured in this and previous studies. Unsworth et al (1981) used an arthrograph similar to the one used in this study to measure stiffness in the flexion/extension plane. Their arthrograph was not driven; the relaxed finger was moved into a position of flexion or extension and the resistive torque was measured at that position. Using their arthrograph they were able to study the equilibrium position of the joint, that is the angle between the long axis of the metacarpal and the long axis of the proximal phalanx, when the joint had zero torque acting on it. Table 8.13 presents the range, mean and standard deviation of equilibrium position reported in their study for comparison with the present study.

The 55 subjects studied by Unsworth et al were aged between 18 and 25 years. Twenty six of the subjects were female. They found that the equilibrium position of the right index mcp joint varied between 16 and 44 degrees of flexion, this agrees with the

TABLE 8.13

COMPARISON OF MEAN EQUILIBRIUM POSITION
WITH RESULTS FROM A PREVIOUS STUDY

	RANGE	MEAN	STD DEV
ALL 55 SUBJECTS	16 - 44	33.2	8.1
26 FEMALES	NOT GIVEN	34.8	6.6
185 FEMALES	11.4 - 44.6	28.94	7.34

range found in the present study. The difference in mean equilibrium position in the two studies is probably due to the difference in sample size.

Helliwell (1987) measured stiffness of the middle finger mcp joint in the adduction/abduction plane of motion and therefore the results obtained in his study cannot be directly compared with the present study. However, if both methods of measuring stiffness are valid then the overall conclusions reached should be similar. In his study only area of the loop and hysteresis, which he calculated as the ratio of the area of the loop to the area of a triangle fitted to the loop, showed a significant difference between patients with rheumatoid arthritis and normal subjects. This agrees with the present finding of significant difference between the two groups in energy dissipation, which was calculated as the area of the hysteresis loop.

Most of the stiffness parameters measured on the arthrograph showed a distinct lack of correlation with the patients subjective assessment of stiffness. Duration of morning stiffness achieved statistically significant correlations with torque range, flexion slope and extension slope. Articular index and subjective stiffness at the time of

interview both achieved statistically significant correlations with extension slope but these correlations were very weak and must be interpreted with caution. Energy dissipation, which was shown to be the objective stiffness parameter which best discriminated between the two groups, had no significant relationship with any of the subjective assessments of stiffness or pain nor with either of the biochemical parameters of disease activity which were recorded. These results suggest that the stiffness parameters measured by the arthrograph are not related to the symptoms complained of by the patients.

CHAPTER 9

LONG TERM MEASUREMENT OF STIFFNESS SWELLING AND GRIP STRENGTH IN HEALTHY WOMEN AND WOMEN WITH RHEUMATOID ARTHRITIS

Rheumatoid arthritis is a chronic disease characterised by pain, stiffness and swelling of the joints and loss of strength. Accurate measurement of these symptoms is necessary to assess the severity of the disease and the response to treatment over a period of time.

The majority of patients follow a course of remissions and exacerbations of disease activity and also report changes in the intensity of their symptoms throughout the day. Previous studies have investigated these changes and reported circadian variation in swelling, grip strength and stiffness in patients and healthy subjects. These studies have been discussed in chapters 2, 3 and 4.

Few studies, except for drug trials which do not include a healthy control group for comparison, have been designed to study change in these symptoms over a longer period of time. Rudge et al (1983) reported cyclical change in pip joint size and grip

strength in 4 out of 7 patients studied throughout two complete menstrual cycles. They also studied 6 healthy women and reported cyclical change of pip joint size in 3, and of grip strength in 2, of these subjects. Heyman (1974) recorded pip joint size of 24 healthy men and women twice daily for five consecutive wednesdays.

This part of the study was designed to investigate and compare the changes which occur in stiffness, grip strength, size of the pip joints and the whole hand in healthy women and in women with rheumatoid arthritis during the course of one year. In the patient group, changes in pain, subjective stiffness, plasma viscosity and haemoglobin were also studied. Table 8.1 lists the details recorded at each clinic visit.

Thirteen healthy women, aged between 17 and 53 years, twenty three women with active rheumatoid arthritis, aged between 27 and 63 years, and three women with progressive systemic sclerosis, aged 50, 63 and 76 years agreed to participate in the study for one year. They were asked to attend for assessment once a month, at the same time of day on each occassion. Unfortunately, due to various circumstances, not all subjects were able to attend

each month for the full year, whilst some patients attended more frequently.

Table 9.1 presents the age, number of visits for assessment, 2nd line and non-steroidal anti-inflamatory (n.s.a.i.) drugs taken by the twenty six patients in the study. One patient was pregnant and therefore not taking any drugs, one patient was taking n.s.a.i. drugs only and one patient was taking analgesic drugs only. Most of the patients were also taking analgesics when required. As this study was not designed to investigate the effects of drug treatment, no attempt was made to regulate the drugs taken by the patients. During the study drug dosage was altered as necessary for each patient. Patients were asked to take their drugs at the same time of day throughout the study, if possible. None of the patients was taking an oral contraceptive drug, nine were post-menopausal and two had had hysterectomy performed.

Oral contraceptives were taken by 5 of the control subjects, none was taking other regular medication. Two of the control subjects were post-menopausal, and one had had a hysterectomy performed.

TABLE 9.1

DETAILS OF TWENTY SIX PATIENTS PARTICIPATING IN THE REPEATED MEASUREMENTS STUDY

AGE	VISITS	2nd LINE DRUGS	N.S.A.I.DRUGS
27	16	AURANOFIN	I. M.
29	7		
29	7	SULPHASALAZINE	I. P
31	12	SULPHASALAZINE, MYOCRISIN	N.
32	8	MYOCRISIN	P.
34	12	SULPHASALAZINE	I.
35	14	SULPHASALAZINE	
35	14	SULPHASALAZINE	B.
38	14	SULPHASALAZINE, MYOCRISIN	D.
38	12	AURANOFIN	N.
41	12	MYOCRISIN	P. F.
42	12	MYOCRISIN	N.
45	12	SULPHASALAZINE	
46	8	SULPHASALAZINE	
48	12	SULPHASALAZINE, MYOCRISIN	T.
48	12	MYOCRISIN	N.
49	7	AZATHIOPRINE, PREDNISOLONE	D.
50	12	AURANOFIN	N.
50	4		
51	4	MYOCRISIN	I.
52	8	SULPHASALAZINE	K.
54	10	METHOTREXATE	N.
55	5	MYOCRISIN	D.
63	10	D PENICILLAMINE	
63	14	SULPHASALAZINE, MYOCRISIN	D.
76	13		I. L.

N.S.A.I.DRUGS KEY

LOREZEPAM = L. INDOMETHACINE = I. KETOPROFEN = K.

PIROXICAM = P. MEFANAMIC ACID = M. BENORYLATE = B.

FENBUFEN = F. TIAPROFENAC ACID = T. DICLOFENAC = D.

NAPROXEN = N.

DATA ANALYSIS

The mean and standard deviation of each variable for each individual subject were calculated and are presented in Appendix 1.

All variables were expressed in standardized form (z-scores) before further analysis.

Correlation coefficients between the arthrographic, clinical and subjective variables were calculated.

One-way analysis of variance was calculated for each variable, between all values obtained throughout the study period, for all subjects.

Principal Components Analysis was used to identify the factors which best represented relationships amongst the variables of each set. The arthrographic and clinical variables were entered into the first analysis. Equilibrium position and grip strength were both identified as highly unique variables, (communality less than 0.1) and they were removed from the analysis. The remaining seven variables were represented by two factors. The subjective variables were entered into the second analysis.

Duration of morning stiffness was the variable with most 'uniqueness' (communality 0.5) but it was not sufficiently unique to require removal from the analysis. The communality of a variable is the total variance of the variable accounted for by the combination of all common factors. The variance that is not accounted for by the common factors is the 'uniqueness' of the variable. Communality can range from 0 to 1, with 0 indicating that the common factors explain none of the variance, and 1 indicating that all the variance is explained by the common factors.)

Stepwise multiple linear regression analysis was used to quantify the relationships amongst the derived factors and some of the original variables. In this method the variable with the largest positive or negative correlation with the dependent variable is entered into the equation first, successive variables are entered according to the same criteria until all variables with a probability associated with the F test of 0.05 or less have been entered. Multiple R is the correlation coefficient between the dependent and independent variables. Adjusted R square reflects the goodness of fit of the model to the population rather than the sample from which it was derived. (If R square = 1 all

observations fall on a straight line, if R square = 0 there is no linear relationship, but there may be another assoiciation between the variables). The F statistic tests how well the regression model fits the data. If the probability associated with F is small, the hypothesis that there is no linear relationship between the variables in the population (rather than the sample), is rejected.

All data analyses were performed using an Amdahl computer and SPSS-X software.

RESULTS

At each visit to the clinic pip joint size and grip strength of subjects' right and left hands were measured. Analysis of the data revealed a strong correlation between the pip joint size of right and left hands in both groups (control group r = .9735, patient group r = .9771) and between grip strength of the right and left hands in both groups (control group r = .9596, patient group r = .9717). For this reason, and because the other objective measurements were made on right hands only, it was decided to include only right hand measurements in further analysis.

TABLE 9.2 DESCRIPTION OF CLINICAL VARIABLES

		MEAN	STD DEV	BETWEEN SUBJECT ANOVA		BETWEEN GROUP ANOVA	
				F	Sig.	F	Sig.
RIGHT HAND VOLUME	C	334.77	43.268	167.2928	.0000	28.0696	.0000
	P	357.74	39.988	81.4090	.0000		
PIP JOINTS RIGHT HAND	C	255.70	12.503	433.0289	.0000	91.1926	.0000
	P	270.25	15.323	224.7381	.0000		
GRIP STRENGTH RIGHT HAND	C	313.15	88.059	21.4101	.0000	495.2036	.0000
	P	142.62	63.568	74.2539	.0000		

C = CONTROL GROUP
P = PATIENT GROUP

TABLE 9.3 CORRELATION COEFFICIENTS OF THE CLINICAL AND BIOCHEMICAL VARIABLES

RIGHT HAND PIP SIZE	C	.6589 *		
	P	.6336 *		
RIGHT HAND GRIP STRENGTH	C	.1130	.0748	
	P	-.2178 *	-.2952 *	
PLASMA VISCOSITY	P	.4879 *	.4338 *	-.2542 *
HAEMOGLOBIN	P	-.3209 *	-.4838 *	.4103 *
		RIGHT HAND VOLUME	RIGHT HAND PIP SIZE	RIGHT HAND GRIP STRENGTH

* = Sig. p < .001 ALL OTHERS - N.S.

C = CONTROL GROUP

P = PATIENT GROUP

Table 9.2 presents the mean and standard deviation of right hand volume, pip joint size and grip strength. The between-subject and between-group analysis of variance is also presented.

Table 9.3 presents the correlation coefficients between the three clinical measurements and the two biochemical measurements of disease activity.

GRIP STRENGTH

Analysis of variance showed significant difference between subjects within both groups (control group $F = 21.4101$, patient group $F = 74.2539$). However, the between-group analysis of variance revealed a greater difference between the two groups ($F = 495.20$). The mean grip strength of patients was less than 50% that of the control group, with less scatter around the mean.

Examination of the individual subject data revealed that only 3 patients (11%), in this study and 15 patients (17%), in the single measurement study (described in chapter 8) achieved a grip strength above 200 mm Hg. Of the control group, only one subject (7%) in this study and five (5%) in the

single measurement study failed to achieved a grip strength above 200 mm Hg.

In the control group, grip strength was shown not to have significant correlation with either pip size or hand volume. In the patient group grip strength had negative, statistically significant correlation with both pip size and hand volume.

HAND VOLUME

Analysis of variance revealed that there was a significant difference between individual subject's hand volume, within both groups. There was also a significant difference between the two groups.

Both groups showed a statistically significant correlation between hand volume and pip joint size. There was a weak, statistically significant, negative correlation with grip strength in the patient group.

PIP JOINT SIZE

The patient group had a larger mean pip joint size and standard deviation than the control group. Analysis of variance showed significant difference

TABLE 9.4 INDIVIDUAL SUBJECT PIP JOINT SIZE

CONTROL GROUP				PATIENT GROUP			
MEAN	STD DEV	RANGE		MEAN	STD DEV	RANGE	
240.50	2.56	8	C	244.17	2.08	7	
245.83	1.40	5	C	247.58	2.19	9	
246.33	1.78	6		253.36	2.76	8	
247.83	2.04	8	C	254.00	2.00	7	H
249.00	1.76	5		256.25	5.85	12	P
251.00	1.71	5		258.17	3.27	11	P
251.13	2.36	7	C	260.17	1.75	5	
255.00	2.00	6	P	260.75	2.25	7	H
255.18	2.64	9	P	263.14	1.57	4	
258.58	1.98	6	C	263.62	1.93	7	
268.89	1.96	6		266.00	3.06	8	
279.50	1.51	4		266.50	2.07	5	P
286.56	1.94	6	H	267.14	4.95	13	
				269.20	3.40	11	P
				270.44	2.36	8	
				270.58	3.12	11	
				271.17	4.37	15	
				276.30	3.02	9	P
				278.00	2.35	6	P
				282.00	5.89	18	
C = ORAL CONTRACEPTIVE				287.36	3.05	9	
H = HYSTERECTOMY				287.71	4.42	11	*
P = POST MENOPAUSAL				292.17	2.41	9	
* = PREGNANT				292.86	5.54	16	P
				293.75	3.59	8	P
				297.15	2.08	8	P

between the two groups and also between individual subjects within the two groups.

Table 9.4 lists the individual subject's mean, standard deviation and range of values for pip joint size in both groups, for comparison. The values are listed from smallest to largest. It is clear from this table that the range and standard deviation of pip joint size in the individual was not affected by the mean size. Individuals in the control group varied in size throughout the study by 4 - 9 mm (0.8 - 1.8 mm per pip joint). Individuals in the patient group varied in size throughout the study by 4 - 16 mm (0.8 - 3.2 mm per pip joint). These results suggest that a change in individual pip joint size of more than 2 mm may be disease related. This finding agrees with that of Heyman (1974).

BIOCHEMICAL VARIABLES

In the patient group there were statistically significant correlations between both of the biochemical variables and hand volume, pip joint size and grip strength. These results are presented in Table 9.3.

TABLE 9.5 DESCRIPTION OF ARTHROGRAPHIC VARIABLES

		MEAN	STD DEV	BETWEEN SUBJECT ANOVA		BETWEEN GROUP ANOVA	
				F	Sig.	F	Sig.
EQUILIBRIUM POSITION	C	27.77	8.065	0.9796	.4723	1.8776	.1714
	P	29.04	8.960	1.3516	.1289		
TORQUE RANGE	C	7.35	2.51	10.2175	.0000	8.3562	.0041
	P	8.47	4.08	27.6482	.0000		
DISSIPATED ENERGY	C	1.23	0.41	12.9296	.0000	2.0695	.1511
	P	1.33	0.78	6.5008	.0000		
FLEXION SLOPE	C	2.32	1.010	4.2927	.0000	12.4813	.0005
	P	2.99	2.104	18.1576	.0000		
EXTENSION SLOPE	C	2.25	0.988	11.9928	.0000	3.5056	.0619
	P	2.51	1.458	31.1012	.0000		
MID SLOPE	C	1.04	0.377	8.1678	.0000	1.5758	.2101
	P	1.10	0.557	18.6365	.0000		

C = CONTROL GROUP
P = PATIENT GROUP

TABLE 9.6 CORRELATION COEFFICIENTS OF THE ARTHROGRAPHIC VARIABLES

TORQUE RANGE	C	.0693	+				
	P	.2346					
DISSIPATED ENERGY	C	.0482	+	.9108			
	P	.2494		.8474			
FLEXION SLOPE	C	.1413	+	.8274	.6710		
	P	.1733	*	.8297	.6529		
EXTENSION SLOPE	C	-.1620	*	.7266	.7204	.4012	
	P	.0377	+	.7354	.6740	.3999	
MID-POSITION SLOPE	C	.0697	+	.8382	.8223	.6682	.5558
	P	.2168		.8922	.7417	.6946	.6546
		EQUILIBRIUM POSITION		TORQUE RANGE	DISSIPATED ENERGY	FLEXION SLOPE	EXTENSION SLOPE

+ - N.S. * - P < .05 ALL OTHER - P < .001

C = CONTROL GROUP 133 MEASUREMENTS ON 13 SUBJECTS

P = PATIENT GROUP 262 MEASUREMENTS ON 26 SUBJECTS

ARTHROGRAPHIC VARIABLES

Table 9.5 presents the mean and standard deviation of the arthrographic variables, the between subject analysis of variance (ANOVA) for each group and the between group analysis of variance.

These results show that there was a significant difference between individuals within both groups in the observed variance of all the arthrographic variables except equilibrium position. However, only torque range ($F = 8.3562$) and flexion slope ($F = 12.4813$) showed a significant difference between the two groups.

Coefficients of correlation between the arthrographic variables were calculated and are presented in Table 9.6. In both groups the strongest relationships were between torque range and dissipated energy.

SUBJECTIVE VARIABLES

The subjective variables, right hand index, articular index, morning pain, pain at the time of interview, morning stiffness, stiffness at the time of interview and duration of morning stiffness could

TABLE 9.7 CORRELATION COEFFICIENTS OF THE SUBJECTIVE VARIABLES WITH THE ARTHROGRAPHIC VARIABLES

	TORQUE RANGE	DISSIPATED ENERGY	FLEXION SLOPE	EXTENSION SLOPE	MID-POSITION SLOPE
RIGHT HAND INDEX	.2548 P .000	.1517 P .007	.2196 P .000	.2259 P .000	.2515 P .000
ARTICULAR INDEX	.2461 P .000	.1220 P .024	.2267 P .000	.2045 P .000	.2161 P .000
MORNING PAIN	.2795 P .000	.1451 P .009	.1953 P .001	.2794 P .000	.2388 P .000
PAIN AT INTERVIEW	.2183 P .000	.1142 P .032	.1426 P .010	.2346 P .000	.1936 P .001
MORNING STIFFNESS	.2386 P .000	.1439 P .010	.1748 P .002	.2324 P .000	.1752 P .002
STIFFNESS AT INTERVIEW	.2515 P .000	.1464 P .009	.1655 P .004	.2821 P .000	.2136 P .000
DURATION OF STIFFNESS	.2072 P .000	.1481 P .009	.0347 P .291	.2972 P .000	.2310 P .000

TABLE 9.8 CORRELATION COEFFICIENTS OF THE SUBJECTIVE VARIABLES WITH THE CLINICAL VARIABLES

	RIGHT HAND VOLUME	RIGHT HAND PIP SIZE	RIGHT HAND GRIP STRENGTH
RIGHT HAND INDEX	.2186 P .000	.2432 P .000	-.3503 P .000
ARTICULAR INDEX	.1601 P .004	.2153 P .000	-.4833 P .000
MORNING PAIN	.2062 P .000	.3717 P .000	-.5444 P .000
PAIN AT INTERVIEW	.2183 P .000	.2697 P .000	-.3893 P .000
MORNING STIFFNESS	.1372 P .012	.3384 P .000	-.4152 P .000
STIFFNESS AT INTERVIEW	.1468 P .008	.2239 P .000	-.3006 P .000
DURATION OF STIFFNESS	.1493 P .008	.1913 P .001	-.3188 P .000

be measured by the patient group only. Therefore all data analysis presented in this section refers to the patient group only.

Table 9.7 presents the coefficients of correlation and P values between the arthrographic and subjective variables. Equilibrium position was not included in the table as there was no statistically significant correlation with any of the subjective variables. Duration of stiffness and flexion slope had no significant correlation. All other variables showed weak, significant correlations with each other.

Table 9.8 presents the coefficients of correlation and P values between the subjective and clinical variables. Grip strength had significant negative correlation with all the subjective variables. Pip joint size and hand volume had weak, statistically significant correlations with all the subjective variables.

The results discussed so far have shown that the three sets of variables, arthrographic, clinical and subjective, were inter and intra-related. Also, within each group there were individuals who were significantly different from each other in all the

variables measured. In order to identify individuals contributing most to these differences, and check that the results were not a consequence of errors in the data, the Scheffe multiple comparison procedure (alpha 0.05) was used to test for significant difference between all possible pairs of means.

One subject in the control group and two in the patient group were identified as being significantly different from the majority in all the arthrographic variables and were excluded from further analysis. These subjects will be discussed in detail later in the chapter.

Data from the remaining thirty six subjects were entered into the Principal Components analysis.

Table 9.9 presents the communality of the arthrographic variables in the analysis explained by the factors and the variable loading of each factor. The arthrographic variables had high loading on factor 1, which was therefore named 'objective stiffness factor'. Hand volume and pip joint size had high loading on factor 2, this was named 'size factor'.

Table 9.10 presents the communality of the patients

TABLE 9.9

FACTOR ANALYSIS OF ARTHROGRAPHIC VARIABLES

PRINCIPAL COMPONENTS ANALYSIS AND VARIMAX ROTATION

COMMUNALITY

TORQUE RANGE	.95454
DISSIPATED ENERGY	.66267
FLEXION SLOPE	.61192
EXTENSION SLOPE	.68180
MID-POSITION SLOPE	.82836
RIGHT HAND VOLUME	.85619
RIGHT PIP JOINT SIZE	.82683

ROTATED FACTOR MATRIX

	FACTOR 1	FACTOR 2
TORQUE RANGE	.92272	.32115
DISSIPATED ENERGY	.81326	.03570
FLEXION SLOPE	.71916	.30780
EXTENSION SLOPE	.76675	.30643
MID-POSITION SLOPE	.88378	.21748
RIGHT HAND VOLUME	.16973	.90961
RIGHT PIP JOINT SIZE	.27669	.86618

TABLE 9.10 FACTOR ANALYSIS OF SUBJECTIVE DATA

PRINCIPAL COMPONENTS ANALYSIS AND VARIMAX ROTATION

COMMUNALITY

RIGHT HAND INDEX	.90673
ARTICULAR INDEX	.89269
MORNING STIFFNESS	.78360
STIFFNESS AT INTERVIEW	.79493
MORNING PAIN	.78834
PAIN AT INTERVIEW	.81795
DURATION OFF STIFFNESS	.55427

ROTATED FACTOR MATRIX

	FACTOR 1	FACTOR 2
RIGHT HAND INDEX	.12308	.94424
ARTICULAR INDEX	.29193	.89859
MORNING STIFFNESS	.85766	.21914
STIFFNESS AT INTERVIEW	.86918	.19864
MORNING PAIN	.82883	.31841
PAIN AT INTERVIEW	.85604	.29179
DURATION OF STIFFNESS	.74427	.01810

COMMUNALITY - The total variance of a variable accounted for by the combination of all common factors. The variance that is not accounted for by the common factors is the 'uniqueness' of the variable.

ROTATED FACTOR MATRIX - the co-efficients in the table represent both regression weights and correlation co-efficients.

ie. RIGHT HAND INDEX

Factor 1 = .12308 - squared = .0151
Factor 2 = .94424 - squared = .8915

:- 89% of the total variance of right hand index is accounted for by Factor 2 and 1.5% by Factor 1. The remaining 9.5% would be accounted for by factors 3 - 7.

subjective variables in the analysis explained by the factors and the variable loadings of each factor. The patient's subjective assessments of pain and stiffness had high loading on factor 1. This factor was named 'subjective symptoms factor'. Articular index and right hand pain index had high loading on factor 2, which was named 'pain factor'.

Stepwise multiple regression analysis was used to identify the relative importance of each factor or variable in predicting the value of the others. The resultant equations are presented in Tables 9.11 to 9.15. The dependent variable is identified at the top of each table. The Multiple R, Adjusted R Square, F test and significance of F of all variables which satisfied the inclusion criteria (probability < 0.05 to enter) are presented.

These equations show that grip strength and articular index were the most important influences on patients subjective assessment of their disease symptoms. The articular index was the most important influence on grip strength.

Plasma viscosity, haemoglobin and the size factor were closely related. Size factor was also related to the objective stiffness factor, more so in the

TABLE 9.11 MULTIPLE LINEAR REGRESSION ANALYSIS

DEPENDENT VARIABLE :- OBJECTIVE STIFFNESS FACTOR

CONTROL GROUP		PARIENT GROUP	
VARIABLE ENTERED ON STEP 1		VARIABLE ENTERED ON STEP 1	
SIZE FACTOR		PAIN FACTOR	
MULTIPLE R	= .28324	MULTIPLE R	= .21179
ADJ.R SQUARE	= .08022	ADJ R SQUARE	= .04047
F	= 11.42583	F	= 10.23791
Signif. F	= .0010	Signif. F	= .0016
VARIABLE ENTERED ON STEP 2		VARIABLE ENTERED ON STEP 2	
GRIP STRENGTH		SIZE FACTOR	
MULTIPLE R	= .36573	MULTIPLE R	= .28447
ADJ.R SQUARE	= .13376	ADJ.R SQUARE	= .07245
F	= 10.03693	F	= 9.55337
Signif. F	= .0001	Signif.F	= .0001

TABLE 9.12 MULTIPLE LINEAR REGRESSION ANALYSIS

DEPENDENT VARIABLE :- SUBJECTIVE SYMPTOMS FACTOR

PATIENT GROUP

VARIABLE ENTERED ON STEP 1
GRIP STRENGTH

MULTIPLE R	=	.27944
ADJ.R SQUARE	=	.07386
F	=	18.46422
Signif. F	<	.00005

VARIABLE ENTERED ON STEP 2
ARTICULAR INDEX

MULTIPLE R	=	.31844
ADJ.R SQUARE	=	.09312
F	=	12.24429
Signif. F	<	.00005

TABLE 9.13 MULTIPLE LINEAR REGRESSION ANALYSIS

PATIENT GROUP

DEPENDENT VARIABLES :- PLASMA VISCOSITY

VARIABLE ENTERED ON STEP 1
SIZE FACTOR

MULTIPLE R	=	.52536
ADJ.R SQUARE	=	.27268
F	=	83.10686
Signif. F	<	.00005

VARIABLE ENTERED ON STEP 2
PAIN FACTOR

MULTIPLE R	=	.63030
ADJ.R SQUARE	=	.39173
F	=	71.51849
Signif. F	<	.00005

HAEMOGLOBIN

VARIABLE ENTERED ON STEP 1
SIZE FACTOR

MULTIPLE R	=	.38557
ADJ.R SQUARE	=	.14476
F	=	38.06876
Signif. F	<	.00005

VARIABLE ENTERED ON STEP 2
GRIP STRENGTH

MULTIPLE R	=	.46278
ADJ.R SQUARE	=	.20692
F	=	29.56908
Signif. F	<	.00005

TABLE 9.14 MULTIPLE REGRESSION ANALYSIS

DEPENDENT VARIABLE :- GRIP STRENGTH

CONTROL GROUP

VARIABLE ENTERED ON STEP 1
OBJECTIVE STIFFNESS FACTOR

MULTIPLE R	=	.25816
ADJ.R SQUARE	=	.05952
F	=	9.35432
Signif.F	=	.0027

PATIENT GROUP

VARIABLE ENTERED ON STEP 1
ARTICULAR INDEX

MULTIPLE R	=	.46007
ADJ.R SQUARE	=	.20805
F	=	58.53323
Signif.F	<	.00005

VARIABLE ENTERED ON STEP 2
HAEMOGLOBIN

MULTIPLE R	=	.53583
ADJ.R SQUARE	=	.28054
F	=	43.69732
Signif.F	<	.00005

VARIABLE ENTERED ON STEP 3
SUBJECTIVE SYMPTOMS FACTOR

MULTIPLE R	=	.55195
ADJ.R SQUARE	=	.29499
F	=	31.54490
Signif.F	<	.00005

TABLE 9.15 MULTIPLE REGRESSION ANALYSIS

DEPENDENT VARIABLE :- SIZE FACTOR

PATIENT GROUP

VARIABLE ENTERED ON STEP 1
PLASMA VISCOSITY

MULTIPLE R	=	.52536
ADJ.R SQUARE	=	.27268
F	=	83.10686
Signif.F	<	.00005

VARIABLE ENTERED ON STEP 2
HAEMOGLOBIN

MULTIPLE R	=	.59444
ADJ.R SQUARE	=	.34730
F	=	59.29035
Signif.F	<	.00005

VARIABLE ENTERED ON STEP 3
OBJECTIVE STIFFNESS VARIABLE

MULTIPLE R	=	.61803
ADJ.R SQUARE	=	.37338
F	=	44.49720
Signif.F	<	.00005

control group than the patient group where pain factor was the more important influence. However these equations (table 9.11) were the least statistically significant of the regression analyses.

DISCUSSION

The results of this study confirm that grip strength is the variable which best discriminates between patients with rheumatoid arthritis and healthy control subjects. Using one particular dynamometer it appeared that a reading below 200 mm Hg was abnormal. Unfortunately, this figure cannot be used as a standard as the size of the inflatable bag and calibration of the dynamometer will affect the reading. The new strain gauged, computer controlled dynamometers should remedy this (Jones et al 1985; Helliwell 1987). Grip strength was more significantly related to generalised joint tenderness (articular index) than to tenderness of the joints in the hand and appeared to influence patients assessment of the severity of their pain and stiffness more than any other variable.

Although size of the pip joints and volume of the whole hand did not differentiate clearly between

patients and healthy control subjects, the variation in these measurements over the study period was a clear indication of disease activity. A variation of more than 2 mm in size of any one pip joint appears to be abnormal. The strongest influence upon the size factor was plasma viscosity, followed by haemoglobin which had a negative correlation. Size or swelling of the pip joints and the hand did not influence patients assessment of their symptoms but did have an influence upon the objective stiffness factor particularly in the control group. This suggests that there is a 'normal' amount of stiffness present in the index mcp joint of the hand which is related to size, when the size of the hand or pip joints is increased the relationship between size and stiffness becomes distorted.

Rudge et al (1983) reported change in pip joint size and grip strength related to the menstrual cycle. The results of this study could not be used to confirm or deny the presence of a cyclical variation in those women who were menstruating. The original intention was to assess all subjects at intervals of twenty eight days throughout the year. Those subjects who were menstruating should then be seen during the same stage of their menstrual cycle at each visit and the cyclical variation would be

minimised. In fact, due to the irregularity of the womens menstrual cycles and their failure to attend clinic on the correct date, few subjects were seen at the same stage of their cycle on each occassion.

The two patients whose objective stiffness variables were pinpointed by the Scheffe test as being significantly different from the majority of subjects in the study were identified as patients number 19 and 26 (mean and standard deviation of their variables are presented in appendix 1). Both of these patients were suffering from progressive systemic sclerosis and were extremely stiff throughout the study period. The third patient with systemic sclerosis (number 24)was not significantly different from the majority of patients with rheumatoid arthritis. Helliwell (1987) studied three patients with scleroderma and found all three to be extremely stiff.

One subject in the control group was pinpointed by the Scheffe test as being significantly different from the majority in all the arthrographic variables. She was identified as subject No. 9 (mean and standard deviation of her variables are listed in appendix 1). This subject attended for assessment on eight occassions. During that time it

became apparent that she was suffering from an affective disorder. She was then admitted to hospital for treatment of her condition and withdrawn from the study. It was not possible to say whether her mental condition was connected to her increased stiffness but it poses interesting possibilities which may be investigated in the future.

CHAPTER 10

CONCLUSIONS

The arthrograph was developed in response to a need for an objective method of measuring stiffness in the joints of patients with rheumatoid arthritis. It has been found to be acceptable to patients and easily operated by staff after minimal tuition. The test takes little time to complete and results are immediately available on screen and as hard copy for inclusion in patients notes.

In order for arthrography to be of value in the routine assessment of disease activity and response to treatment, objective stiffness, as measured by the arthrograph, must be shown to be altered by the disease process and related to other indices of disease activity.

Arthrography has been used in the past to study the contribution of various tissues to total joint stiffness (Johns and Wright 1962; Helliwell 1987); changes in stiffness following various forms of physiotherapy (Yung 1981; Helliwell 1987); changes in stiffness following intra-articular injection of steroids, intra-venous methylprednisolone and a

single oral dose of ibuprofen (Helliwell 1987). Circadian variation of objective stiffness has been recorded in both healthy control subjects (Yung 1981) and in patients with rheumatoid disease (Helliwell 1987).

This study was designed to investigate the validity of arthrographic measurement of objective stiffness at the right index metacarpophalangeal (mcp) joint in relation to other subjective and objective methods of assessment of disease activity.

The single measurement study (chapter 8) revealed no significant relationship between objective stiffness at the mcp joint, measured on the arthrograph, and patients subjective assessment of the duration or severity of their stiffness. The arthrograph measured no difference in the amount of stiffness present in the joints of the healthy control group and the group of patients with rheumatoid disease. Repeated measurements (chapter 9) revealed a greater difference of stiffness between individuals within both groups than between the two groups. As none of the subjects in the control groups complained of feeling stiff it appears that the arthrograph does not measure the symptom referred to by patients as 'stiffness'.

Grip strength, measured by one person using the same dynamometer throughout the study, was found to be the measurement which best discriminated between patients and healthy control subjects. It was found to be the variable which best correlated with all the subjective assessments of stiffness and pain but there was no relationship with objective stiffness of the index mcp joint. Neither size of the hand nor pip joint size influenced grip strength in patients or control subjects. Generalised joint tenderness, assessed by the Ritchie articular index, had a greater influence upon grip strength than tenderness of the hand joints alone. The new strain gauged computer controlled dynamometers, capable of measuring the strength of individual fingers as well as total grip strength, will enable more detailed study of the relationship between joint tenderness and grip strength to be undertaken.

Weakness assessed by grip strength and joint tenderness assessed by Ritchie Articular Index were the predominant influences upon patients subjective assessment of stiffness. This finding supports past suggestions that patients are confused in their understanding of the symptom 'stiffness'. This confusion may result from the common practice of

asking patients to quantify their symptoms in terms of duration of early morning stiffness alone. Morning stiffness has long been regarded as an important measure of disease activity (Cobb et al 1954; Lansbury 1956; Pinals et al 1981), although there is no evidence that physicians or patients are agreed on the definition of the symptom.

Several previous studies have investigated this misinterpretation of symptoms. Rhind et al (1987) found that when patients were asked to explain what they meant by stiffness most included a pain descriptor and limited movement in their definition. Wright (1959) suggested that patients may be confusing muscle weakness with joint stiffness.

Proximal inter-phalangeal (pip) joint size had a greater influence upon objective stiffness of the index mcp joint than did total hand volume, particularly in the control group. In the patient group, changes in pip joint size were related to changes in plasma viscosity and haemoglobin estimation. Variation in size of individual pip joints by more than 2mm was seen in the patient group only and can therefore be regarded as disease related.

Plasma viscosity, a biochemical indicator of disease activity, was the predominant influence on the size of patients hands and pip joints but was not related to objective stiffness. The stronger relationship observed between size and objective stiffness in the control subjects suggests that although active rheumatoid arthritis, reflected in increased plasma viscosity, causes an increase in hand and pip joint size it does not cause a corresponding increase in joint stiffness.

This altered relationship between size and stiffness was also reported by Helliwell (1987). He measured finger size immediately distal to the web and noted that, compared with a group of normal subjects, patients with active rheumatoid arthritis had decreased stiffness relative to size.

The design of this study did not allow investigation of the effect of the menstrual cycle upon objective joint stiffness. In view of the influence of pip joint size on objective stiffness and the previously reported cyclical change in pip joint size and grip strength (Rudge et al., 1981; 1983), this should be investigated in the future.

SECTION 4

APPENDIX 1

INDIVIDUAL SUBJECT DATA

PATIENT NO. 1

AGE 27 YEARS. NUMBER OF VISITS = 16

	MEAN	STD DEV
EQUILIBRIUM POSITION	24.25	8.20
TORQUE RANGE	4.66	1.48
DISSIPATED ENERGY	0.87	0.37
FLEXION SLOPE	1.42	0.75
EXTENSION SLOPE	1.42	0.51
MID-POSITION SLOPE	0.55	0.20
RIGHT HAND VOLUME	334.75	9.08
RIGHT PIP JOINT SIZE	270.44	2.36
RIGHT GRIP STRENGTH	102.06	13.87
RIGHT HAND INDEX	0.44	0.81
ARTICULAR INDEX	5.81	4.65
MORNING PAIN	4.50	1.75
PAIN AT INTERVIEW	2.69	1.40
MORNING STIFFNESS	3.94	1.69
STIFFNESS AT INTERVIEW	1.63	0.81
DURATION OF STIFFNESS	25.31	13.35
PLASMA VISCOSITY	1.68	0.04
HAEMOGLOBIN	10.76	0.52

PATIENT NO. 2

AGE 29 YEARS NUMBER OF VISITS = 7

	MEAN	STD DEV
EQUILIBRIUM POSITION	34.00	5.35
TORQUE RANGE	15.90	3.17
DISSIPATED ENERGY	1.71	0.32
FLEXION SLOPE	9.06	2.55
EXTENSION SLOPE	2.56	0.84
MID-POSITION SLOPE	1.60	0.36
RIGHT HAND VOLUME	419.28	4.75
RIGHT PIP JOINT SIZE	287.71	4.42
RIGHT GRIP STRENGTH	169.43	18.86
RIGHT HAND INDEX	1.14	1.07
ARTICULAR INDEX	7.71	4.23
MORNING PAIN	1.86	2.34
PAIN AT INTERVIEW	0.57	0.53
MORNING STIFFNESS	3.57	1.81
STIFFNESS AT INTERVIEW	1.57	0.79
DURATION OF STIFFNESS	30.00	0.00
PLASMA VISCOSITY	1.59	0.04
HAEMOGLOBIN	12.05	0.92

PATIENT NO. 3

AGE 29 YEARS NUMBER OF VISITS = 7

	MEAN	STD DEV
EQUILIBRIUM POSITION	22.89	5.33
TORQUE RANGE	2.61	0.51
DISSIPATED ENERGY	0.42	0.21
FLEXION SLOPE	0.62	0.27
EXTENSION SLOPE	0.56	0.39
MID-POSITION SLOPE	0.43	0.20
RIGHT HAND VOLUME	318.57	7.99
RIGHT PIP JOINT SIZE	263.14	1.57
RIGHT GRIP STRENGTH	94.14	4.56
RIGHT HAND INDEX	5.71	1.98
ARTICULAR INDEX	22.00	6.60
MORNING PAIN	5.14	1.57
PAIN AT INTERVIEW	3.29	1.11
MORNING STIFFNESS	4.57	0.98
STIFFNESS AT INTERVIEW	2.57	1.27
DURATION OF STIFFNESS	49.29	14.27
PLASMA VISCOSITY	1.67	0.07
HAEMOGLOBIN	11.03	0.93

PATIENT NO. 4

AGE 31 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	25.37	9.36
TORQUE RANGE	6.26	0.95
DISSIPATED ENERGY	1.08	0.16
FLEXION SLOPE	2.16	0.56
EXTENSION SLOPE	1.80	0.22
MID-POSITION SLOPE	0.84	0.15
RIGHT HAND VOLUME	405.67	15.91
RIGHT PIP JOINT SIZE	282.00	5.89
RIGHT GRIP STRENGTH	154.75	26.46
RIGHT HAND INDEX	1.67	1.83
ARTICULAR INDEX	6.75	4.96
MORNING PAIN	4.33	1.67
PAIN AT INTERVIEW	4.50	1.78
MORNING STIFFNESS	3.75	2.09
STIFFNESS AT INTERVIEW	3.25	1.71
DURATION OF STIFFNESS	59.58	41.48
PLASMA VISCOSITY	1.77	0.08
HAEMOGLOBIN	11.19	0.26

PATIENT NO. 5

AGE 32 YEARS NUMBER OF VISITS = 8

	MEAN	STD DEV
EQUILIBRIUM POSITION	33.58	8.10
TORQUE RANGE	7.37	2.31
DISSIPATED ENERGY	1.24	0.26
FLEXION SLOPE	2.27	1.61
EXTENSION SLOPE	2.23	0.46
MID-POSITION SLOPE	1.12	0.37
RIGHT HAND VOLUME	335.75	6.65
RIGHT PIP JOINT SIZE	260.75	2.25
RIGHT GRIP STRENGTH	141.38	20.37
RIGHT HAND INDEX	0.63	0.91
ARTICULAR INDEX	8.75	6.09
MORNING PAIN	5.50	3.34
PAIN AT INTERVIEW	5.13	3.31
MORNING STIFFNESS	5.88	3.64
STIFFNESS AT INTERVIEW	5.75	3.28
DURATION OF STIFFNESS	131.25	102.60
PLASMA VISCOSITY	1.59	0.06
HAEMOGLOBIN	12.95	0.67

PATIENT NO. 6

AGE 34 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	28.63	10.83
TORQUE RANGE	7.48	2.07
DISSIPATED ENERGY	1.05	0.38
FLEXION SLOPE	3.09	0.87
EXTENSION SLOPE	1.44	0.44
MID-POSITION SLOPE	1.03	0.32
RIGHT HAND VOLUME	336.08	6.17
RIGHT PIP JOINT SIZE	260.17	1.75
RIGHT GRIP STRENGTH	188.42	40.88
RIGHT HAND INDEX	0.00	0.00
ARTICULAR INDEX	3.00	2.13
MORNING PAIN	2.58	1.73
PAIN AT INTERVIEW	1.25	1.14
MORNING STIFFNESS	1.67	1.30
STIFFNESS AT INTERVIEW	0.33	0.65
DURATION OF STIFFNESS	10.00	6.74
PLASMA VISCOSITY	1.54	0.04
HAEMOGLOBIN	12.23	0.40

PATIENT NO 7

AGE 35 YEARS NUMBER OF VISITS = 14

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.55	9.24
TORQUE RANGE	9.22	2.73
DISSIPATED ENERGY	2.02	0.73
FLEXION SLOPE	2.82	0.92
EXTENSION SLOPE	2.71	0.80
MID-POSITION SLOPE	1.29	0.42
RIGHT HAND VOLUME	344.14	8.09
RIGHT PIP JOINT SIZE	263.62	1.93
RIGHT GRIP STRENGTH	217.30	36.86
RIGHT HAND INDEX	0.64	1.50
ARTICULAR INDEX	6.00	3.39
MORNING PAIN	1.36	1.50
PAIN AT INTERVIEW	1.0	0.96
MORNING STIFFNESS	1.57	1.55
STIFFNESS AT INTERVIEW	0.57	0.65
DURATION OF STIFFNESS	13.21	10.67
PLASMA VISCOSITY	1.62	0.06
HAEMOGLOBIN	13.51	0.34

PATIENT NO. 8

AGE 35 YEARS NUMBER OF VISITS = 14

	MEAN	STD DEV
EQUILIBRIUM POSITION	30.51	11.44
TORQUE RANGE	6.57	0.98
DISSIPATED ENERGY	1.62	2.09
FLEXION SLOPE	2.14	0.73
EXTENSION SLOPE	2.23	0.30
MID-POSITION SLOPE	0.75	0.19
RIGHT HAND VOLUME	302.64	17.32
RIGHT PIP JOINT SIZE	253.36	2.76
RIGHT GRIP STRENGTH	143.93	16.77
RIGHT HAND INDEX	1.14	1.83
ARTICULAR INDEX	6.21	4.33
MORNING PAIN	3.00	3.04
PAIN AT INTERVIEW	1.79	1.97
MORNING STIFFNESS	3.14	2.66
STIFFNESS AT INTERVIEW	1.79	2.36
DURATION OF STIFFNESS	66.79	62.87
PLASMA VISCOSITY	1.54	0.03
HAEMOGLOBIN	11.89	0.57

PATIENT NO. 9

AGE 38 YEARS NUMBER OF VISITS = 14

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.38	8.58
TORQUE RANGE	8.10	2.21
DISSIPATED ENERGY	1.11	0.17
FLEXION SLOPE	3.02	2.01
EXTENSION SLOPE	2.11	0.57
MID-POSITION SLOPE	1.02	0.23
RIGHT HAND VOLUME	383.14	11.69
RIGHT PIP JOINT SIZE	287.36	3.05
RIGHT GRIP STRENGTH	159.00	32.60
RIGHT HAND INDEX	6.36	1.98
ARTICULAR INDEX	25.21	5.06
MORNING PAIN	4.43	2.24
PAIN AT INTERVIEW	2.64	2.13
MORNING STIFFNESS	4.36	2.06
STIFFNESS AT INTERVIEW	1.78	1.76
DURATION OF STIFFNESS	61.79	48.86
PLASMA VISCOSITY	1.64	0.07
HAEMOGLOBIN	11.80	0.37

PATIENT NO.10

AGE 38 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.53	13.69
TORQUE RANGE	6.10	1.12
ENERGY DISSIPATION	1.11	0.18
FLEXION SLOPE	1.86	0.47
EXTENSION SLOPE	2.00	0.38
MID-POSITION SLOPE	0.78	0.25
RIGHT HAND VOLUME	355.42	12.58
RIGHT PIP JOINT SIZE	254.00	2.00
RIGHT GRIP STRENGTH	198.16	33.29
RIGHT HAND INDEX	2.33	1.30
ARTICULAR INDEX	20.08	3.55
MORNING PAIN	5.67	1.44
PAIN AT INTERVIEW	7.17	1.27
MORNING STIFFNESS	6.00	1.95
STIFFNESS AT INTERVIEW	7.41	1.50
DURATION OF STIFFNESS	60.00	0.00
PLASMA VISCOSITY	1.65	0.08
HAEMOGLOBIN	13.65	0.40

PATIENT NO. 11

AGE 41 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	33.46	6.88
TORQUE RANGE	9.96	2.22
DISSIPATED ENERGY	1.20	0.21
FLEXION SLOPE	3.69	2.03
EXTENSION SLOPE	2.83	0.73
MID-POSITION SLOPE	1.24	0.27
RIGHT HAND VOLUME	363.55	7.00
RIGHT PIP JOINT SIZE	271.17	4.37
RIGHT GRIP STRENGTH	118.08	6.70
RIGHT HAND INDEX	0.50	0.67
ARTICULAR INDEX	6.00	2.04
MORNING PAIN	6.08	1.24
PAIN AT INTERVIEW	4.75	1.29
MORNING STIFFNESS	4.08	1.68
STIFFNESS AT INTERVIEW	2.67	0.98
DURATION OF STIFFNESS	41.25	14.48
PLASMA VISCOSITY	1.63	0.08
HAEMOGLOBIN	11.76	0.35

PATIENT NO. 12

AGE 42 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.03	10.79
TORQUE RANGE	6.73	0.86
DISSIPATED ENERGY	1.14	0.19
FLEXION SLOPE	2.19	0.39
EXTENSION SLOPE	1.77	0.47
MID-POSITION SLOPE	1.08	0.21
RIGHT HAND VOLUME	312.00	13.02
RIGHT PIP JOINT SIZE	244.17	2.08
RIGHT GRIP STRENGTH	179.92	23.14
RIGHT HAND INDEX	2.42	2.27
ARTICULAR INDEX	8.92	3.94
MORNING PAIN	1.17	0.72
PAIN AT INTERVIEW	1.50	1.09
MORNING STIFFNESS	1.33	1.23
STIFFNESS AT INTERVIEW	2.08	1.24
DURATION OF STIFFNESS	30.00	40.09
PLASMA VISCOSITY	1.55	0.04
HAEMOGLOBIN	13.19	0.38

PATIENT NO. 13

AGE 45 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	31.64	6.95
TORQUE RANGE	8.20	1.79
DISSIPATED ENERGY	1.20	0.20
FLEXION SLOPE	3.24	1.37
EXTENSION SLOPE	2.29	0.37
MID-POSITION SLOPE	1.03	0.21
RIGHT HAND VOLUME	359.17	7.50
RIGHT PIP JOINT SIZE	270.58	3.12
RIGHT GRIP STRENGTH	311.00	16.84
RIGHT HAND INDEX	0.00	0.00
ARTICULAR INDEX	0.58	0.79
MORNING PAIN	0.58	1.44
PAIN AT INTERVIEW	0.50	1.45
MORNING STIFFNESS	0.00	0.00
STIFFNESS AT INTERVIEW	0.00	0.00
DURATION OF STIFFNESS	0.00	0.00
PLASMA VISCOSITY	1.61	0.05
HAEMOGLOBIN	12.26	0.41

PATIENT NO. 14

AGE 46 YEARS NUMBER OF VISITS = 8

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.93	10.39
TORQUE RANGE	6.32	1.50
DISSIPATED ENERGY	1.13	0.21
FLEXION SLOPE	2.09	0.79
EXTENSION SLOPE	1.96	0.44
MID-POSITION SLOPE	0.82	0.11
RIGHT HAND VOLUME	347.57	2.76
RIGHT PIP JOINT SIZE	266.00	3.06
RIGHT GRIP STRENGTH	156.00	21.23
RIGHT HAND INDEX	1.29	0.76
ARTICULAR INDEX	9.43	2.57
MORNING PAIN	3.71	2.43
PAIN AT INTERVIEW	2.57	2.37
MORNING STIFFNESS	1.57	1.90
STIFFNESS AT INTERVIEW	0.71	1.50
DURATION OF STIFFNESS	11.43	18.42
PLASMA VISCOSITY	1.60	0.05
HAEMOGLOBIN	11.80	0.25

PATIENT NO. 15

AGE 48 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.26	7.05
TORQUE RANGE	11.42	2.21
DISSIPATED ENERGY	1.62	0.30
FLEXION SLOPE	5.01	1.58
EXTENSION SLOPE	3.11	0.85
MID-POSITION SLOPE	1.24	0.30
RIGHT HAND VOLUME	374.08	13.80
RIGHT PIP JOINT SIZE	292.17	2.41
RIGHT GRIP STRENGTH	101.83	12.03
RIGHT HAND INDEX	9.50	3.48
ARTICULAR INDEX	28.08	6.64
MORNING PAIN	8.08	0.90
PAIN AT INTERVIEW	6.67	0.78
MORNING STIFFNESS	7.83	1.40
STIFFNESS AT INTERVIEW	6.42	0.67
DURATION OF STIFFNESS	2.50	16.30
PLASMA VISCOSITY	1.71	0.07
HAEMOGLOBIN	11.09	0.73

PATIENT NO. 16

AGE 48 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	28.61	8.16
TORQUE RANGE	5.94	1.52
DISSIPATED ENERGY	0.99	0.21
FLEXION SLOPE	2.14	0.78
EXTENSION SLOPE	1.65	0.56
MID-POSITION SLOPE	0.75	0.15
RIGHT HAND VOLUME	284.58	13.87
RIGHT PIP JOINT SIZE	247.58	2.19
RIGHT GRIP STRENGTH	102.92	21.37
RIGHT HAND INDEX	2.58	1.68
ARTICULAR INDEX	20.08	6.13
MORNING PAIN	3.33	1.30
PAIN AT INTERVIEW	1.83	0.72
MORNING STIFFNESS	2.67	1.87
STIFFNESS AT INTERVIEW	1.33	1.07
DURATION OF STIFFNESS	20.00	14.77
PLASMA VISCOSITY	1.60	0.08
HAEMAGLOBIN	14.00	0.54

PATIENT NO. 17

AGE 49 YEARS NUMBER OF VISITS = 7

	MEAN	STD DEV
EQUILIBRIUM POSITION	35.79	7.43
TORQUE RANGE	7.20	1.67
DISSIPATED ENERGY	1.06	0.27
FLEXION SLOPE	3.12	0.76
EXTENSION SLOPE	1.30	0.15
MID-POSITION SLOPE	0.98	0.30
RIGHT HAND VOLUME	346.57	15.02
RIGHT PIP JOINT SIZE	267.14	4.95
RIGHT GRIP STRENGTH	64.00	8.70
RIGHT HAND INDEX	7.14	4.34
ARTICULAR INDEX	35.14	4.22
MORNING PAIN	5.57	2.23
PAIN AT INTERVIEW	4.57	1.72
MORNING STIFFNESS	3.71	1.50
STIFFNESS AT INTERVIEW	2.00	1.15
DURATION OF STIFFNESS	70.71	52.47
PLASMA VISCOSITY	1.65	0.06
HAEMOGLOBIN	12.53	0.26

PATIENT NO. 18

AGE 50 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.34	4.93
TORQUE RANGE	10.93	2.00
DISSIPATED ENERGY	1.38	0.23
FLEXION SLOPE	2.20	0.89
EXTENSION SLOPE	5.14	1.14
MID-POSITION SLOPE	1.52	0.38
RIGHT HAND VOLUME	422.67	18.09
RIGHT PIP JOINT SIZE	258.17	3.27
RIGHT GRIP STRENGTH	74.17	5.13
RIGHT HAND INDEX	0.08	0.29
ARTICULAR INDEX	11.00	4.16
MORNING PAIN	4.25	2.18
PAIN AT INTERVIEW	3.17	1.95
MORNING STIFFNESS	4.00	1.86
STIFFNESS AT INTERVIEW	2.67	1.92
DURATION OF STIFFNESS	75.00	79.37
PLASMA VISCOSITY	1.64	0.08
HAEMOGLOBIN	11.62	0.45

PATIENT NO. 19

AGE 50 YEARS NUMBER OF VISITS = 4

	MEAN	STD DEV
EQUILIBRIUM POSITION	19.62	6.92
TORQUE RANGE	20.95	3.75
DISSIPATED ENERGY	1.95	0.49
FLEXION SLOPE	10.05	4.18
EXTENSION SLOPE	5.95	1.10
MID-POSITION SLOPE	2.21	0.36
RIGHT HAND VOLUME	379.75	3.77
RIGHT PIP JOUINT SIZE	293.75	3.59
RIGHT GRIP STRENGTH	94.00	14.44
RIGHT HAND INDEX	5.25	1.50
ARTICULAR INDEX	26.50	5.97
MORNING PAIN	8.25	1.71
PAIN AT INTERVIEW	6.25	4.50
MORNING STIFFNESS	8.00	1.15
STIFFNESS AT INTERVIEW	8.00	1.15
DURATION OF STIFFNESS	ALL DAY	0.00
PLASMA VISCOSITY	1.76	0.06
HAEMOGLOBIN	11.97	0.34

PATIENT NO. 20

AGE 51 YEARS NUMBER OF VISITS = 4

	MEAN	STD DEV
EQUILIBRIUM POSITION	37.00	10.21
TORQUE RANGE	8.03	0.63
DISSIPATED ENERGY	1.27	0.22
FLEXION SLOPE	2.54	0.60
EXTENSION SLOPE	2.39	0.39
MID-POSITION SLOPE	1.06	0.21
RIGHT HAND VOLUME	307.50	8.27
RIGHT PIP JOINT SIZE	256.25	5.85
RIGHT GRIP STRENGTH	262.50	48.93
RIGHT HAND INDEX	0.25	0.50
ARTICULAR INDEX	1.50	1.73
MORNING PAIN	0.25	0.50
PAIN AT INTERVIEW	0.50	0.58
MORNING STIFFNESS	0.00	0.00
STIFFNESS AT INTERVIEW	0.00	0.00
DURATION OF STIFFNESS	0.00	0.00
PLASMA VISCOSITY	1.65	0.06
HAEMOGLOBIN	12.42	0.25

PATIENT NO. 21

AGE 52 YEARS NUMBER OF VISITS = 8

	MEAN	STD DEV
EQUILIBRIUM POSITION	25.50	7.45
TORQUE RANGE	5.64	1.01
DISSIPATED ENERGY	0.86	0.17
FLEXION SLOPE	1.81	0.48
EXTENSION SLOPE	1.87	0.56
MID-POSITION SLOPE	0.79	0.15
RIGHT HAND VOLUME	389.00	25.94
RIGHT PIP JOINT SIZE	266.50	2.07
RIGHT GRIP STRENGTH	128.38	14.71
RIGHT HAND INDEX	6.25	2.31
ARTICULAR INDEX	16.50	4.00
MORNING PAIN	7.25	0.71
PAIN AT INTERVIEW	6.25	0.89
MORNING STIFFNESS	7.13	0.83
STIFFNESS AT INTERVIEW	6.00	0.76
DURATION OF STIFFNESS	99.38	17.81
PLASMA VISCOSITY	1.66	0.08
HAEMOGLOBIN	11.83	0.53

PATIENT NO. 22

AGE 54 YEARS NUMBER OF VISITS = 10

	MEAN	STD DEV
EQUILIBRIUM POSITION	28.12	9.68
TORQUE RANGE	12.54	5.11
DISSIPATED ENERGY	1.89	1.03
FLEXION SLOPE	4.58	2.35
EXTENSION SLOPE	4.06	1.30
MID-POSITION SLOPE	1.67	0.85
RIGHT HAND VOLUME	404.30	15.70
RIGHT PIP JOINT SIZE	276.30	3.02
RIGHT GRIP STRENGTH	76.20	19.19
RIGHT HAND INDEX	24.40	10.07
ARTICULAR INDEX	44.40	9.42
MORNING PAIN	5.90	1.37
PAIN AT INTERVIEW	5.20	0.92
MORNING STIFFNESS	5.20	1.99
STIFFNESS AT INTERVIEW	4.30	1.34
DURATION OF STIFFNESS	63.00	79.17
PLASMA VISCOSITY	1.96	0.14
HAEMOGLOBIN	11.46	0.49

PATIENT NO. 23

AGE 55 YEARS NUMBER OF VISITS = 5

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.84	7.87
TORQUE RANGE	7.74	0.67
DISSIPATED ENERGY	1.29	0.15
FLEXION SLOPE	3.13	0.32
EXTENSION SLOPE	1.71	0.58
MID-POSITION SLOPE	0.95	0.02
RIGHT HAND VOLUME	392.20	33.61
RIGHT PIP JOINT SIZE	278.00	2.35
RIGHT GRIP STRENGTH	55.20	7.22
RIGHT HAND INDEX	0.25	0.50
ARTICULAR INDEX	12.75	2.75
MORNING PAIN	5.60	1.34
PAIN AT INTERVIEW	2.60	0.89
MORNING STIFFNESS	5.20	1.09
STIFFNESS AT INTERVIEW	1.40	1.67
DURATION OF STIFFNESS	33.00	16.43
PLASMA VISCOSITY	1.76	0.11
HAEMOGLOBIN	12.16	0.28

PATIENT NO. 24

AGE 63 YEARS NUMBER OF VISITS = 10

	MEAN	STD DEV
EQUILIBRIUM POSITION	26.80	7.44
TORQUE RANGE	4.51	0.96
DISSIPATED ENERGY	0.79	0.32
FLEXION SLOPE	1.46	0.51
EXTENSION SLOPE	1.06	0.54
MID-POSITION SLOPE	0.53	0.18
RIGHT HAND VOLUME	325.10	11.38
RIGHT PIP JOINT SIZE	269.20	3.40
RIGHT GRIP STRENGTH	196.30	15.41
RIGHT HAND INDEX	0.10	0.32
ARTICULAR INDEX	0.30	0.67
MORNING PAIN	3.00	3.27
PAIN AT INTERVIEW	2.70	2.58
MORNING STIFFNESS	7.90	0.99
STIFFNESS AT INTERVIEW	4.00	3.59
DURATION OF STIFFNESS	58.50	35.00
PLASMA VISCOSITY	1.60	0.05
HAEMOGLOBIN	13.43	0.47

PATIENT NO. 25

AGE 63 YEARS NUMBER OF VISITS = 14

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.70	8.90
TORQUE RANGE	9.66	2.32
DISSIPATED ENERGY	1.37	0.46
FLEXION SLOPE	2.93	0.90
EXTENSION SLOPE	3.45	1.27
MID-POSITION SLOPE	1.34	0.49
RIGHT HAND VOLUME	412.93	16.06
RIGHT PIP JOINT SIZE	292.86	5.54
RIGHT GRIP STRENGTH	122.43	27.89
RIGHT HAND INDEX	0.71	0.61
ARTICULAR INDEX	3.21	2.29
MORNING PAIN	2.57	2.59
PAIN AT INTERVIEW	2.00	2.42
MORNINMG STIFFNESS	1.21	1.97
STIFFNESS AT INTERVIEW	0.86	1.88
DURATION OF STIFFNESS	37.50	43.53
PLASMA VISCOSITY	1.84	0.14
HAEMOGLOBIN	12.79	0.43

PATIENT NO. 26

AGE 76 YEARS NUMBER OF VISITS = 13

	MEAN	STD DEV
EQUILIBRIUM POSITION	26.88	8.12
TORQUE RANGE	16.63	3.58
DISSIPATED ENERGY	2.93	0.72
FLEXION SLOPE	4.85	1.23
EXTENSION SLOPE	5.77	1.36
MID-POSITION SLOP	2.46	0.59
RIGHT HAND VOLUME	358.15	17.72
RIGHT PIP JOINT SIZE	297.15	2.08
RIGHT GRIP STRENGTH	64.00	8.31
RIGHT HAND INDEX	5.00	3.72
ARTICULAR INDEX	20.69	5.91
MORNING PAIN	8.69	1.11
PAIN AT INTERVIEW	6.62	1.61
MORNING STIFFNESS	8.38	1.39
STIFFNESS AT INTERVIEW	6.46	1.56
DURATION OF STIFFNESS	136.15	76.11
PLASMA VISCOSITY	1.56	0.07
HAEMOGLOBIN	10.78	0.52

CONTROL SUBJECT NO. 1

AGE 17 YEARS NUMBER OF VISITS = 10

	MEAN	STD DEV
EQUILIBRIUM POSITION	25.27	8.95
TORQUE RANGE	7.52	0.69
DISSIPATED ENERGY	1.20	0.10
FLEXION SLOPE	2.18	0.58
EXTENSION SLOPE	2.36	0.38
MID-POSITION SLOPE	1.07	0.10
RIGHT HAND VOLUME	353.30	5.74
RIGHT PIP JOINT SIZE	249.00	1.76
RIGHT GRIP STRENGTH	342.50	41.03

CONTROL SUBJECT NO. 2

AGE 20 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.29	9.40
TORQUE RANGE	7.60	2.41
DISSIPATED ENERGY	1.27	0.25
FLEXION SLOPE	2.77	1.42
EXTENSION SLOPE	1.86	0.26
MID-POSITION SLOPE	1.06	0.27
RIGHT HAND VOLUME	339.58	8.08
RIGHT PIP JOINT SIZE	258.58	1.98
RIGHT GRIP STRENGTH	357.17	34.04

CONTROL SUBJECT NO. 3

AGE 23 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	28.25	8.44
TORQUE RANGE	4.70	0.75
DISSIPATED ENERGY	0.85	0.16
FLEXION SLOPE	1.39	0.42
EXTENSION SLOPE	1.52	0.22
MID-POSITION SLOPE	0.65	0.11
RIGHT HAND VOLUME	289.00	7.53
RIGHT PIP JOINT SIZE	245.83	1.40
RIGHT GRIP STRENGTH	303.25	9.45

CONTROL SUBJECT NO. 4

AGE 25 YEARS NUMBER OF VISITS = 8

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.49	9.30
TORQUE RANGE	6.41	1.55
DISSIPATED ENERGY	1.03	0.17
FLEXION SLOPE	1.90	0.88
EXTENSION SLOPE	1.84	0.40
MID-POSITION SLOPE	0.87	0.16
RIGHT HAND VOLUME	315.87	9.63
RIGHT PIP JOINT SIZE	251.13	2.36
RIGHT GRIP STRENGTH	138.50	13.93

CONTROL SUBJECT NO. 5

AGE 25 YEARS NUMBER OF VISITS = 8

	MEAN	STD DEV
EQUILIBRIUM POSITION	31.94	5.05
TORQUE RANGE	5.12	1.03
DISSIPATED ENERGY	0.75	0.19
FLEXION SLOPE	1.67	0.61
EXTENSION SLOPE	1.58	0.41
MID-POSITION SLOPE	0.62	0.21
RIGHT HAND VOLUME	328.63	6.12
RIGHT PIP JOINT SIZE	240.50	2.56
RIGHT GRIP STRENGTH	282.25	23.30

CONTROL SUBJECT NO. 6

AGE 26 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	27.72	9.60
TORQUE RANGE	7.08	1.35
DISSIPATED ENERGY	1.13	0.20
FLEXION SLOPE	2.06	0.36
EXTENSION SLOPE	2.19	0.58
MID-POSITION SLOPE	0.95	0.16
RIGHT HAND VOLUME	307.58	8.46
RIGHT PIP JOINT SIZE	247.83	2.04
RIGHT GRIP STRENGTH	271.75	19.24

CONTROL SUBJECT NO. 7

AGE 29 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	28.53	8.66
TORQUE RANGE	7.30	1.76
DISSIPATED ENERGY	1.22	0.21
FLEXION SLOPE	2.29	0.86
EXTENSION SLOPE	2.02	0.36
MID-POSITION SLOPE	1.56	0.19
RIGHT HAND VOLUME	317.42	14.31
RIGHT PIP JOINT SIZE	251.00	1.71
RIGHT GRIP STRENGTH	404.83	37.53

CONTROL SUBJECT NO. 8

AGE 35 YEARS NUMBER OF VISITS = 9

	MEAN	STD DEV
EQUILIBRIUM POSITION	25.90	7.63
TORQUE RANGE	8.07	1.59
DISSIPATED ENERGY	1.44	0.27
FLEXION SLOPE	2.42	0.63
EXTENSION SLOPE	2.60	0.39
MID-POSITION SLOPE	1.17	0.19
RIGHT HAND VOLUME	399.22	9.85
RIGHT PIP JOINT SIZE	268.89	1.96
RIGHT GRIP STRENGTH	373.78	155.18

CONTROL SUBJECT NO. 9

AGE 38 YEARS NUMBER OF VISITS = 8

	MEAN	STD DEV
EQUILIBRIUM POSITION	29.86	10.06
TORQUE RANGE	12.43	4.69
DISSIPATED ENERGY	2.05	0.82
FLEXION SLOPE	3.68	1.82
EXTENSION SLOPE	4.34	1.97
MID-POSITION SLOPE	1.73	0.79
RIGHT HAND VOLUME	371.00	14.43
RIGHT PIP JOINT SIZE	279.50	1.51
RIGHT GRIP STRENGTH	454.23	61.68

CONTROL SUBJECT NO. 10

AGE 40 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	30.75	6.27
TORQUE RANGE	6.02	1.12
DISSIPATED ENERGY	0.96	0.16
FLEXION SLOPE	2.26	0.53
EXTENSION SLOPE	1.47	0.24
MID-POSITION SLOPE	0.94	0.38
RIGHT HAND VOLUME	297.00	12.95
RIGHT PIP JOINT SIZE	246.33	1.78
RIGHT GRIP STRENGTH	314.83	53.03

CONTROL SUBJECT NO. 11

AGE 48 YEARS NUMBER OF VISITS = 9

	MEAN	STD DEV
EQUILIBRIUM POSITION	22.18	6.25
TORQUE RANGE	8.85	2.11
DISSIPATED ENERGY	1.50	0.22
FLEXION SLOPE	2.69	0.87
EXTENSION SLOPE	3.34	1.15
MID-POSITION SLOPE	1.16	0.33
RIGHT HAND VOLUME	488.56	19.74
RIGHT PIP JOINT SIZE	286.56	1.94
RIGHT GRIP STRENGTH	212.67	37.24

CONTROL SUBJECT NO. 12

AGE 51 YEARS NUMBER OF VISITS = 12

	MEAN	STD DEV
EQUILIBRIUM POSITION	25.71	6.01
TORQUE RANGE	8.93	1.66
DISSIPATED ENERGY	1.53	0.30
FLEXION SLOPE	2.98	1.08
EXTENSION SLOPE	2.69	0.80
MID-POSITION SLOPE	1.23	0.26
RIGHT HAND VOLUME	329.25	10.10
RIGHT PIP JOINT SIZE	255.00	2.00
RIGHT GRIP STRENGTH	309.33	33.55

CONTROL SUBJECT NO. 13

AGE 53 YEARS NUMBER OF VISITS = 11

	MEAN	STD DEV
EQUILIBRIUM POSITION	26.86	7.29
TORQUE RANGE	6.67	1.05
DISSIPATED ENERGY	1.14	0.19
FLEXION SLOPE	2.06	0.55
EXTENSION SLOPE	2.04	0.46
MID-POSITION SLOPE	0.93	0.20
RIGHT HAND VOLUME	304.45	5.05
RIGHT PIP JOINT SIZE	255.18	2.64
RIGHT GRIP STRENGTH	276.27	26.93

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