Injury Incidence in Adolescent Rowers Within England: A Prospective Study

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INJURY INCIDENCE IN ADOLESCENT ROWERS WITHIN ENGLAND: A PROSPECTIVE STUDY

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Abstract

Contemporary research analysing injury incidence in junior rowers is lacking, and what has been published has focused solely on performance-level athletes. The purpose of this study was to investigate injury incidence in junior rowers from grassroot clubs and school rowing programmes across England. The study also explored if injury rates were influenced by gender, training, or geographical region. Finally, the results of the report would offer suggestion if socioeconomic status might be associated with injuries in junior rowers. The study adopted a positivist, prospective approach examining mainly quantitative injury data from a cohort of 1530 rowers aged 12-18 years (803 females and 727 males) across 34 rowing clubs, covering all regions. Coaches completed an anonymous injury questionnaire to record injuries in junior rowers over a six-month period. The following variables were compared; gender, age, height, weight, hours trained, injury site, attainment, classification, injury reoccurrence, and severity. 56.7% of females reported injuries, in comparison to 41.7% of males. Out of 727 males, 3.3% reported an injury to their coach, and from 803 females, 3.8% recorded injuries. Injuries were most common in junior rowers aged 16 compared to younger age groups. There were no notable differences between hours engaging in exercise training, but injury rates were lower as years of experience increased, as most reports were from rowers who had been training for 1-2 years, followed by those training 3-4 years. 88% of injuries were sustained in the training environment as opposed to during competition. Muscle and tendon-related overuse injuries were the most common injuries, with the most reported site being the trunk (38.3 ± 14.3). Finally, the highest injury rates were reported from clubs located in the top 40% of the most deprived neighbourhoods in England. These findings have relevance to athlete injury prevention strategies and impending future research into the factors associated with injury prevalence, both physiological and sociological. Moreover, additional research into junior injury incidence in rowers has the capacity to support the findings of this study and promote suitable interventions to reduce the occurrences of injuries in rowing, supporting long-term continuity of the sport.

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Abbreviations

LBP lower back pain

RSF rib stress fracture

SES – Socioeconomic Status

Chapter One: Introduction

Rowing is a competitive sport that was established in England in 1715, originating on the River Thames with The Doggett's Coat and Badge race (Hammer, 2012), which still operates today (Nauright, 2012; Lucas, 2016). Despite the historical background of rowing for males, competitive women's rowing did not formulate until 1945, with participation heavily class-driven (Taylor, 2016). Gender differences in junior rowing also presented themselves within international racing, with the first recorded junior race for boys in 1967, and the first girls racing event over 10 years later (FISA, 2018).

The rowing stroke is comprised of a repetitive compression and extension motion from the front of the stroke (the catch), through to the back of the stroke (the finish), with force exerted through the oars; moving the boat through the water (Thornton *et al.,* 2016). There are currently 550 affiliated rowing clubs across England (British Rowing 2019_a), with 625,500 participants in 2019 (British Rowing, 2020_b), seeing an increase in membership rates of almost 40% between 2015-2017; 250000 rowers aged 14+ were reportedly actively rowing. It has been suggested that the increase in participation rates reflect an amplified uptake of rowing by females (Keenan, 2018). After London 2012 Olympics, British Rowing saw a 50% increase in female rowing participation, using role models such as gold medallist Katherine Grainger as an advocate for women's sport (British Rowing, 2016_d). Supporting this notion, Keenan (2018) reported no significant changes in men's participation rates in the sport from 1995-2018 ($P=0.899$), whereas female participation rates have risen by approximately 113 females each year, providing a strongly linear increase ($r^2=0.847$, $P=0.0001$).

The UK's racing system possesses classifications for each category, separating participants by age, gender, weight, and ability (Smith, 2018). When categorising by age, junior athletes are identified as any individual competing under the age of eighteen, racing per corresponding academic year (World Rowing, 2014). Whereas senior racing (for those aged 18+) and masters events (subjective age of 27+), are divided by ability and British Rowing's racing points structure (British

Rowing 2018$_{b}$; British Rowing 2018$_{c}$; Caroe, 2018$_{a}$). Additionally, senior and master's events are divided by their weight categories; lightweight and heavyweight (Slater *et al.,* 2005). Rowing is a later specialisation sport, where juniors are advised not to participate until they reach academic year seven, or eleven years old (British Rowing, 2019$_{c}$). There is a significant body of research revolving around the elite international athlete yet in comparison, insufficient documentation from grassroot participation level upwards (Smoljanovic *et al.,* 2009; Wilson *et al.,* 2010; Lawton, 2012; Newlands *et al.,* 2015). To date, research on junior rowers has focused on the international performance level only (Marinovic and Kosovic, 2017). However, junior rowers make up ~37% of total membership (British Rowing, 2019$_{e}$), and have been identified as the target focus group to increase rowing membership numbers, in a bid to sustain rowers and promote long-term athlete development using the school-age rowing strategy.

Fitt (2009) defined amateurism as athletes who participate in sport for enjoyment purposes as opposed to monetary benefits. Within amateur rowing clubs, Wigglesworth (2004) reported membership to be consisting of a high proportion of middle-class participants, which has resulted in a social stigma over the years as being a 'wealthy' sport (Brown, 1999; Caudwell, 2011). This can be reflected in tangible requirements of the sport such as the attire of club blazers (Stern, 2015), the expenses required to equip a boathouse and the equipment required to participate (Cosmell, 2010). The House of Commons (2017) reported the highest rates of inactivity in those who are unemployed or from lower socio-economic status backgrounds. This would suggest why there is scarce research relating economic status to injury prevalence data in rowing. In more recent years, British Rowing (2018$_{a}$) have committed to increasing participation rates working with juniors from low-income areas, on pupil premium or from Black, Asian, and Minority Ethnic (BAME) groups, funding coaches through the Henley Royal Regatta Charitable Trust and Sport England, to increase access to those who otherwise would not have the opportunity to participate. The early work from Williams *et al.,* (1997) recognised a need for research comparing socioeconomic status (SES) with adolescent injuries, reporting a higher risk exposure as SES decreases. Mahboob *et al.,* (2019) recently expressed a need from Public Health

England to take SES into consideration when measuring health equity in injury prevention programming. Moreover, the work of Zuckerman *et al.,* (2017) reported that those with private healthcare return to sport quicker than those who rely on public health services.

Neglecting the physical adaptations and key maturation stages with junior rowers, including overtraining and overloading, may result in injury or drop out (Mallac, 2018). There is evidence to suggest that factors such as core instability, strength inadequacy and poor technique can increase the risk of junior injuries and drop-out (Bellarmine University, 2010; Hosea and Hannafin, 2012). Other risks include specialising too early (Roach and Maffulli, 2003), lack of awareness of physical limits and boundaries (Morrison, 2018) and inadequate warm-up and cool-downs (Smoljanovic *et al.,* 2009). There is a wealth of research evidence covering the risk of injuries in senior rowing, for instance lumbar flexion and extension patterns at the finish of the stroke aggravating LBP (Wilson *et al.,* 2014); or the training errors that can onset nerve impingements and rib stress fractures (RSF) (Karlson, 2015). However, few have attempted to quantify the incidence of injury and most common types of injuries according to age groups and performance levels (Baugh and Kerr, 2016).

There is also contradictory evidence surrounding injury rates between males and females, including reasoning as to why sex differences in injuries exist in rowing (Baugh and Kerr, 2016). For example, a plethora of research has highlighted an increased risk of overuse injuries solely in female athletes (Cuff *et al.,* 2010; Yang *et al.,* 2012; Frank *et al.,* 2017; Ruddick *et al.,* 2019). However, many studies include only one sex when reviewing sports injury epidemiology, thus limiting the generalisability of the research (Clay *et al.,* 2016; Richardson *et al.,* 2017). There is a need for sport injury research that includes both male and female athletes to focus on one sport in isolation, as opposed to multi-sports (Aicale *et al.,* 2018; Sugimoto *et al.,* 2019).

On the whole, there is a demand for data surrounding junior athletes and the risk of injuries associated with sport (Steffen and Engebretsen, 2010). Specifically with respect to the sport of rowing, Yang *et al.*, (2012) identified a need for further research into overuse injuries in female junior rowers, as did Baugh and Kerr (2016) who concluded that more research is required into sex-specific differences in junior injury rates in rowing. There is a lack of continuation of injury surveillance in junior rowing, resulting in insufficient evidence to inform on how best to support the development of junior rowers from all backgrounds, and all participation levels through to performance. Therefore, the three key questions for this research were:

1. What is the incidence of injury in junior rowing?
2. Is there evidence for an influence of gender, age, training, and region on injury incidence in junior rowers?
3. Is SES a confounding variable within injury prevalence in rowing?

Chapter Two: Literature review

2.1 Background

In order to understand injury risk in rowers and with regard to gender and age, it is important to consider the structure of sport and the physiological demands associated. The review highlights how rowing formalised as a sport and a governing body, including membership rates and how this impacts on the general rowing population. Physiological demands breaks down the rowing stroke to pinpoint the sequence, and the anatomical associations required to complete the stroke, for instance flexibility and energy systems.

The Formalisation of Rowing as a Sport

Historically known as a form of transportation, fixed seat rowing dates back to ancient Egypt using boats as warships and transportation (Edgerton, 1927; Foley and Soedel, 1981; Tilley, 2007; International Olympic Committee, 2019; British Rowing, 2020$_a$). It is believed that men competed in the sport of rowing from as early as the seventeenth century, formalising as a 'Regata' in Venice (Horn, 2019). Amateurism progressed in the eighteenth century along with the development of the racing shell, otherwise known as the streamlined version of a rowing boat; (Dodd, 1995). Key historical races that identified themselves in this time period include the Oxford Cambridge Boat Race, inaugurated in 1829 (Morgan, 1873), followed by The Henley Royal Regatta in 1832 (Steinacker and Secher, 1993). Rowing formalised as an Olympic sport in Paris 1900, with women competing from Montreal Olympics 1976 (International Olympic Committee, 2015; UK Sport, 2019). Fédération Internationale des Sociétés d'Aviron, otherwise known as FISA, governs international rowing, setting the standards and rules for the participation and safe practice of the sport, whilst overseeing 156 global rowing federations (World Rowing, 2018). Fixed seat rowing is present today within Paralympic rowing (Andrews *et al.*, 2017), and coastal rowing on rough waters in gig clubs, using wide-set boats to minimise risk of capsizing (Dixon, 2014). Today, rowing as a sport is defined as a sliding seat boat, propelling through water using oars and travelling backwards (Three Rivers Rowing Association, 1999; Gianchandani, 2011; International Olympic Committee, 2015).

Sweeping and Sculling

Sweeping and sculling are the two types of rowing, changing the setup of the boat; in particular the rigging and the blade count (Karlson, 1998; Goldblatt and Acton, 2012). Sculling requires two blades per oarsmen and can be trained in a single, double, quadruple or octuple (Strauss, 2001), with a maximum of 16 blades in the boat at one time. Whereas sweep rowing only requires one oar per rower (Hagerman 1984), for bow side (on the left of the shell) or stroke side on the right. There must be an equal number of oars on each side, which is why sweep rowers can only train in pairs, fours, and eights (Rumball *et al.*, 2005). Despite the similarity of both sculling and sweeping producing asymmetrical movements up and down the slide, sweep rowing requires axial and lateral trunk rotation at the catch in order to secure blade placement at full slide (Mattes and Wolff, 2019). The final differentiation between sculling and sweeping is the age of participation. British Rowing (2010) enables juniors to scull from ages 11 onwards, whereas sweeping is only permitted for those aged 15 and over; providing they are structurally developed to withstand applying uneven pressure through one side of the body (Mattes and Wolff, 2019). This is why British Rowing recommends juniors to regularly alternate sides when sweeping to avoid dominance, therefore reducing the risk of injury (Aiken, 2014).

Membership and Racing: Gender Split and Age Divisions

Formerly known as the Amateur Rowing Association, rowing’s national governing body (NGB) in England is British Rowing (British Rowing, 2011). The organisation covers grassroots participation through to the Olympic and Paralympic Games (British Rowing, 2016_a); overseeing both indoor and outdoor rowing. Regarding participation rates, The School Age Rowing Strategy reported a decline in participation rates in rowing from 2017 to 2019, falling from 770,900 active rowers to 640,000 (British Rowing, 2019_e). This decline in participation has yet to be pinpointed to a single event however, to counter this decline, British Rowing (2016_c) have identified multiple ways to assist increasing club membership rates. These include;

1. The School Age Rowing Strategy: providing welcoming and inclusive environments whilst funding support for grassroot and school-based clubs (British Rowing, 2020$_{c}$).
2. Offering learn-to-row resources to teachers leading indoor rowing in schools (British Rowing, 2020$_{d}$).
3. Intra- and inter- school competitions to introduce newcomers to indoor rowing racing (British Rowing, 2015$_{d}$).
4. Case studies to motivate female rowers through school games events (British Rowing, 2019$_{f}$).
5. The latest development of the Love Rowing Charitable Foundation, providing grants and guidance to clubs targeting underrepresented communities including those with disabilities or from BAME backgrounds (Love Rowing, 2019).

Racing is split into two seasons; head season covering winter through spring, and regatta season for the summer ending in autumn; the key differences being the length of the race and the structure of the event (British Rowing, 2015$_{b}$). In both seasons, events are divided into open races and female races, as British Rowing (2012) allows female athletes to substitute into men's crews, but female races to be strictly for females only, avoiding a competitive advantage (Gartland, 2015). Within regatta season, races approach a head-to-head competition style side-by-side across multiple lanes (Muehlbauer *et al.*, 2010), with the exception of time trial events (Smith and Hopkins, 2012). These races cover short distances such as 500m and 750m courses; Dawkins *et al.,* (2018) reported the most common but also the furthest distance covering 2000m. In comparison, head racing follows structure of a time trial order in separate morning and afternoon divisions. Head races set crews off individually at intervals, with the incentive of overtaking another crew (Head of the River Race, 1999).

Racing is also divided into weighted events; lightweight and open weight. Lightweight men and women must weigh under 72.5kg and 59kg respectively, with an increase in weight during head season (World Rowing, 2015_a; British Rowing 2017_a). Achieving weight in restricted events have reported damaging practices such as self-induced vomiting and the use of laxatives (Kazemi *et al.*, 2011). Short-term side effects of rapid weight loss include short-term memory and fatigue (Franchini *et al.*, 2012), with longer-term effects of body dysmorphia, impaired growth, and risk of depression (Berkovich *et al.*, 2015). Juniors are not permitted to race in weighted events until J18 (British Rowing, 2015_a), as work by Moran (2018) recognised safety concerns from making weight on the physiological impact of developing athletes. This is supported by the work of Hall and Lane (2001) and Chang (2005), who identified the implications of young athletes adhering to weigh restrictions; emphasising dieting and dehydration on increased long-term health risks, impairing performance, increased risk of injuries and eating disorders. Once rowers reach the age of 18, they are less likely to be susceptible to puberty adaptations and should have experienced full maturity (Brown *et al.*, 2017), permitting responsibility to manage weight expectations.

Gender and Participation in Rowing

Despite females starting later (Harville, 1974), the increase in female participation rates is unmistakable in membership reports (British Rowing, 2013), where male to females show a 52-48% split respectively, and a 50-50% split in junior rowing. Within the last decade, British Rowing (2016_b) have actively introduced projects aiming to impact female participation rates and overcome identified barriers (Lovell *et al.*, 2010). These barriers include changing the culture of female sport (Harkness, 2012), fear of judgement (Somerset and Hoare, 2018), money (Feizabadi *et al.*, 2011), time constraints (Reichert *et al.*, 2005) and opportunities available (McLoughlin *et al.*, 2016). The increase in female participation was thought to be linked to London's 2012 Olympics, believing it had a significant impact on 'inspiring the nation' (Olympics Report, 2012); thus acknowledging the decline in membership rates in the years to follow, as the novelty of the high-profile event wore off (Whetstone, 2017). In the face of equality and performance sport, women's competitions still do not receive the same recognition: it has taken until the 21st century for women to achieve equality at international events (British Rowing, 2017_b; World Rowing, 2017), yet still at national level, female entries decrease parallel with age (World Rowing, 2015_b).

2.2 Technical Aspects

The Sequence in Action

Breaking down the rowing stroke, there are four identifiable phases that a rower refers to; catch, finish, drive, and recovery (Buyukdemirtas *et al.*, 2014). The development of the optimal stroke sequence has performance enhancements on increased boat speed (Smith and Loschner, 2002), as well as injury prevention benefits (Clay *et al.*, 2016). Examining the biomechanics of the sequence, Arumugam *et al.*, (2020) reported that minor changes in the rowing stroke can largely impact joint positioning and stress; increasing the risk of injury contraction (Bull and McGregor, 2000).

Figure 1: Schematics of the different phases of the rowing stroke (Perich, 2010).

1. *The Catch*

Considering the catch position in **Figure 1** a), the leg and hip joint are compressed to a 90° angle with the shins perpendicular to the water (Fenner, 2006), whilst knees are fully loaded to take the drive (Rumball *et al.*, 2005), and arms are extended to gain full reach at the catch (Halliday *et al.*, 2014). Energy is stored in the back, legs and arms which are equipped to take the stroke (Hosea and Hannafin, 2012). Achieving the optimal catch position supports the connection of force through the blades within the water, to sustain full compression through the stroke

(Caroe, 2018$_b$). Novice rowers and any athletes who have ingrained poor technique, or those exhibiting high levels of fatigue are at an increased risk of over-compressing the knee joint by loading through the lumbar spine and collapsing the shoulders (Rumball, 2005; Clay *et al.,* 2016; Perea, 2019); resulting in potential lateral knee pain or other patellofemoral complaints (Karlson, 2000) and LBP (Rumball *et al.*, 2005; Arumugam *et al.,* 2020). Furthermore, placing undue stress through the trunk during the drive phase, as opposed to the sequencing of legs, body and arms, can increase the risk of injury exposure to the ribs (Vinther, 2009). In addition to utilising a strong catch position to support the drive phase, Caroe (2016) reported that equally distributing the placement of the gluteals on the seat and the feet upon the foot plate, with strong engagement of the glutes support exhibiting a balanced catch; minimising disruptions to the drive phase and therefore reduced risk of injury attainment (Caroe, 2018$_b$).

2. *The Drive*

Within the early drive phase arms remain extended however the main source of power is exhibited through the legs, hips, core, and back extensors whilst suspending off the oar handles (Caroe, 2011; Wall, 2020). As the back adopts the same position from the catch through the stroke, the legs continue to drive until fully extended and remain in contact with the foot plate upon completion (Caldwell *et al.*, 2003). This is the critical pressure point that drives the motion of the boat through the water (Caroe, 2017). Once the leg drive begins to alleviate, the back swing commences through the hips involving posterior rotation, followed by the arms drawing into the chest (Burnett *et al.,* 2008). Again, if the incorrect technique is adopted during the drive phase, the potential attainment of injuries, in particular LBP, increases significantly (Caldwell *et al.*, 2003).

3. *The Finish*

The finishing point of the stroke is where the handles tap into the lap and the blades extract from the water (Caplan *et al.,* 2009). The blade is then feathered parallel to the water to reduce the risk of catching and offsetting the boat's balance (Perich, 2010). The feathering action has been extensively researched in relation to wrist and tendonitis injuries due to gripping too tight, performing with the incorrect handle sizes or from general overuse causing aggravation (Smoljanovic *et al.,* 2009). If the gluteals and core are not activated, poor posture and curvature to the lumbar spine occur, placing the rower at higher risk of LBP and persistent injuries (NG *et al.,* 2008; Perich *et al.,* 2010). A final implication of an incorrectly adopted finish is poor blade extraction, causing what is known as 'catching a crab' where the blade is caught in the back swirl of the water; slowing down boat speed, offsetting balance or impacting the rower (Star 1975; Gentner *et al.,* 2009). A sharp breaking motion from the blade has been linked with injury reports causing abdominal trauma such as rib fractures, abrasion and bruising in 37.9% of a rowing sample (Franklin *et al.,* 2017; Gomez and Rao, 2020).

4. *The Recovery*

The final phase of the stroke is the recovery, as the rower travels from back stops to front stops (Mallac, 2018), in reverse to the sequence that makes up the drive (Rumball *et al.,* 2005). As the arms extend, anterior pelvic tilt produces the rocking forward motion (Ruth, 2015_b), placing the body in the catch position prior to moving the legs (Fenner, 2006). Setting up the front end appropriately during the recovery reduces the likelihood of overreaching at the catch, therefore minimising the risk of LBP or shoulder injuries (Funder, 2005; Kramer and Wilson, 2016). During the rock over, the rower's weight is transferred back to the plantar fascia (Moore and Dalley, 1999), leaving all but flexion of the knee joint and squaring of the blades to recreate the catch position again (Kerkar, 2019).

2.3 Demands of the Sport

Anatomy of the Rowing Stroke Sequence

Rowing is comprised of cyclic, repetitive motions operating forwards and backwards, similar to other continuous sports such as running and cycling (Zainuddin *et al.,* 2019). This action requires a maximum application of force each stroke to ensure the boat runs efficiently (Mazzone, 1988). In order to achieve maximal distance per stroke, Nilsen *et al.,* (1990) advised that the rower must be able to coordinate the ability to apply a considerable amount of pressure through the appropriate muscle groups, in conjunction with the mastered technique. Thus, there is not one sole muscle group that is responsible for the drive phase and distance travelled (Fenton, 2019). Instead, rowing utilises almost every muscle in the human body (Secher 1993; Kleshnev, 2016), attributing approximately 70% of muscle mass to the rowing stroke due to the involvement of not only the limbs, but the trunk also (Steinacker, 1993). This is supported by the work of Turpin and colleagues (2011), who conducted an electromyographic (EMG) analysis on 23 muscles and reported a significant increase in EMG activity (*p* values ranged from <0.0001 to 0.004) in 22 out of 23 muscles. This also assists in explaining why rowing carries one of the highest energy costs, as Hagerman (1984) identified a caloric expenditure of up to 36 kcal/min^{-1}.

A plethora of research has supported the recognition that rowing is a lower-body dominated sport, demanding both strength and power particularly in the leg drive, to efficiently execute satisfactory distance per stroke (Ingham *et al.,* 2002; Yoshiga and Higuchi, 2003; Guével *et al.,* 2011; Thomas *et al.,* 2011; Lawton *et al.,* 2013; Draghici *et al.,* 2017; Penichet-Tomás and Pueo, 2017). Huang and colleagues (2007) reported that gym-based leg extensions are the most valuable measurement for strength in rowers (Jürimäe *et al.,* 2010), and the strongest predictor for 2000m ergo performance (R^2= 0.807, $p \leq 0.05$). However, when transferring land based ergo times to boat speed, the leg drive is not the singular most important factor (Edgley, 2015). A study conducted by Caroe (2014) analysed both indoor rowing and water-based rowing whilst isolating individual body parts. Results exhibited that the leg drive alone contributed to only 38% of boat speed, whilst the back in isolation attributed to 32.2% and arms alone at 30%; with a greater total distance achieved when all three were recruited sequentially. This provides support for the evolving research investigating the optimal rowing stroke, which over time has moved from focusing on the leg drive in isolation (Sanderson and Martindale, 1986) to acknowledging the importance of developing the kinetic chain (Sanchez, 2019).

Research surrounding the kinetic chain originated from the early work of Reuleaux (1876), later adapted by Steindler (1977), proposing that the arrangement of joints contributed to a movement pattern to perform a desired motor task. In relation to rowing, this refers to the synchronisation of the shoulders, elbows, ribs, spine and trunk, hips, pelvis, knees, and ankles to coordinate an effective stroke (Hawkins, 2000; McDonnell *et al.*, 2012; Sanchez, 2019). Recognising the development of the movement pattern associated with the rowing stroke, Tachibana *et al.*, (2007) reviewed the kinetic chain in more depth; attributing the anterior thigh to leg drive power ($r^2 = 0.508$), and the posterior thigh and lower back to power executed through the trunk swing ($r^2 = 0.493$). More recent research by Buckeridge *et al.*, (2014) acknowledged further elements of the kinetic chain accrediting to maximal power output and performance, including the hip hinge ($r^2 = 0.48$), knee placement and lumbar pelvic kinematics ($R^2 = 0.41$), foot stretcher placement ($R^2 = 0.43$) and pelvic rotation ($R^2 = 0.32$). Furthermore, Mattes *et al.*, (2019) also acknowledged leg power being part of the kinetic chain, whilst relying on appropriate sequencing of the trunk and lower back to maximise power output. Long-term support for developing the kinetic chain is attributed to land training, with strength and conditioning highlighting key aspects of the stroke to assist increasing water speed (Gee *et al.*, 2011). Session content focuses on quadriceps, glutes, hamstrings, erector spinae and latissimus dorsi; all concentrating on stabilisation as well as strength development (O'Donovan, 2015).

Flexibility Requirements

In conjunction with whole muscle production, the rowing stroke requires full range of joint mobility, particularly when achieving maximal catch position (Retailleaua *et al.*, 2017). Although there is evidence to suggest that stretching is an essential element of warming-up prior to rowing (Ruth, 2017), session time constraints often neglect the need to stretch prior to training (Tomek, 2020). The implication of this being that by not engaging in pre- or post- exercise stretching, results in performance detriments and increased risk of injury in sportspeople (Thacker *et al.*, 2004; Witvrouw *et al.*, 2004). Whilst research on the importance of flexibility in rowing is equivocal (Perera and Ariyasinghe (2016), research by McNeely and

Royle (2002), Good (2017) and Gibson (2018) all identified two key principles relating to flexibility: reducing injury occurrence and improving athletic performance through skills development and power production. Additionally, work by both Perich *et al.,* (2010) and Weerts *et al.,* (2019) proposed that a reduction in flexibility for an athlete significantly effects posture, thus impairing performance and increasing injury risk. Applying theory to practice, Yan *et al.,* (2018) recommended that greater flexibility extends the period of time that the oar is underwater, enhancing stroke length and therefore distance travelled per stroke. Focusing on enhancing power production at the earliest point in the stroke, Rodford (2012_b) and Soper *et al.,* (2004) identified ankle flexibility as a fundamental factor in engaging leg suspension within the first quarter of the drive. Supporting this notion, Barrett and Manning (2004) reported that manipulating the setup of the scull can assist in flexibility deficits, such as adjusting foot stretcher height to override inadequate plantar and dorsiflexion to align the patella with toe position.

Research into sweep rowing focuses predominantly on upper back mobility (Gibson, 2018), whereas sculling highlights the requirement of hip flexor suppleness (Retailleau *et al.,* 2017), hamstrings (Mistry *et al.,* 2014) and lumbar flexion (Kasmi *et al.,* 2017). To compress at a 20^{o} trajectory hip angle, rowers must have adequate hip flexor mobility to achieve appropriate anterior rotation (Howell, 1984). In turn, achieving the optimal catch position enhances power output through the stroke (Buckeridge *et al.,* 2016). This supports the earlier work of Rodford (2012_b) who identified knees, hips and ankles as the key joints for maintaining a compressed catch. Additionally, contemporary research by Hooper (2017) analysed the impact of reduced mobility, and the consequences limited hip compression can have on stroke length; deficient hip flexibility contributed to overreaching through the lumbar spine to compensate, therefore weakening the central spinal structure. In turn, poor hip flexibility draws the catch position with posterior pelvic tilt; not only placing demand on trunk flexion but preventing glute engagement from the onset of the drive, limiting distance per stroke (Ng *et al.,* 2013).

Hamstring and lumbar spine flexibility are essential to the stroke due to the relationship between them in the pelvic tilt motion (Mistry *et al.,* 2014). Hamstring range is important in achieving the ideal catch position, through to executing a powerful drive (Kaehler, 2010). Recurring research on hamstring flexibility attributes poor mobility to increased injury risk (Reid and McNair, 2000; Stutchfield and Coleman, 2006), particularly in LBP (Perera and Ariyasinghe, 2016; Özdinçler *et al.*, 2019). In contrast, research by Koley and Likhi (2017) and Ruth (2019) reported no relationship between LBP and hamstring flexibility: with focus group design flaws solely studying flexibility in females, as opposed to both genders (Gonzalez *et al.,* 2018). Researching both genders is crucial, as female athletes are known for improved range of motion in comparison to males potentially as a result of both anatomical function and hormone imbalance (Juhas, 2011), demonstrating participant-bias within the study. Stutchfield and Coleman (2006) linked hamstring flexibility to lumbar flexion and LBP, whereas Soper *et al.,* (2004) and Hooper (2017) attributed restricted lumbar flexion to poor technique; overreaching at the catch due to hip and hamstring inflexibility, rather than lumbar elasticity.

Physiology of Rowing: Energy Systems, Aerobic Contributions and Muscle Fibres

When identifying the prominent energy system for rowing, Shirai *et al.,* (2015) reported that the anaerobic system was the least dominant source of energy; it is essential for onset of racing, but only contributes to 10-30% of total workload. These findings compliment the earlier work of Hagerman *et al.,* (1978), who conducted a six-minute maximal test in rowing and found that the anaerobic system accounted for 30% of total workload. Mäestu *et al.,* (2005) demonstrated that the longer the training session, the more aerobic endurance is required in comparison to anaerobic systems. This is supported by the earlier work of Pripstein *et al.,* (1999), who reported a 12% reduction in anaerobic capacity when extending testing site from six minutes, to seven and a half minutes. Coincidentally, the longer session length is more comparable to a commonly used racing length, the 2000m test (Caudwell, 2011). Furthermore, Shephard (1998) reinforced the prominence of aerobic energy in rowing to slow twitch fibre count in athletes.

Secher (1993) reported that oarsmen possess 70-75% of slow twitch fibres in their skeletal muscle. Moreover, sprint races are associated with high adenosine triphosphate (ATP) turnover, placing demand on the anaerobic energy system from an increased rate in strokes per minute (Bangsbo *et al.,* 1992); as well as an association between maximal oxygen uptake and aerobic energy contributions through muscle glycogen reduction and repetitive muscular contractions (Martin and Tomescu, 2017). In comparison, Otter-Kaufmann *et al.,* (2019) reported that head races exceed 2000m, therefore placing higher demand on aerobic capacity on water (r=0.63), in comparison to anaerobic contributions (r=0.60). Consequently, Cosgrove *et al.,* (1999) suggested that rowers should devote most of their training to the improvement of $\dot{V}O_{2max}$ in order to deal with the negative aspects of the anaerobic work and to buffer the hydrogen ions produced.

2.4 Injuries in Rowing

Sports Injuries and the Complications Defining Them

Sports injuries are defined as a wounded area affecting the musculoskeletal system (NHS, 2020) as a result of sports participation (Powell and Barber-Foss, 1999; Verhagen and Mechelen, 2009; Bahr *et al.,* 2012). Common factors associated with these include limited attention to warm-ups, over training and poor technique (Physician's Review Network, 2016). Fuller *et al.,* (2006) defined a sports injury as any physical complaint from competition or training exposure. Unfortunately, due to the complex nature of sports-related injuries (Bolling *et al.,* 2018), there are a variation of definitions across research (Patel *et al.,* 2017) resulting in potential confusion when conducting research in this area. Despite this, many definitions appear to cross reference similar themes including;

- Recovery time (Nielsen *et al.,* 2014).
- Repetitive trauma (Chéron *et al.,* 2017).
- Athlete-exposure (Patel and Baker, 2006).
- Requirement of medical attention (Patel and Nelson, 2000)
- Barriers to participation (Bueno *et al.,* 2018).

Furthermore, the work of Brukner and Khan (2014) classified rowing injuries into nine key sites;

1. Bone fractures
2. Cartilage damage
3. Joint dislocations
4. Ligament sprains and inflammations
5. Muscular strains and tears
6. Tendinopathy and tears to tendons
7. Bursitis
8. Nerve irritations
9. Skin abrasions.

Mechelen *et al.,* (2012) and Parkkari *et al,* (2012) reported that across sports, the severity of the injury can be recorded interchangeably based on the nature of the injury, duration of treatment, training time lost, lifelong effects and cost of treatment. Severity is ranked on the elapsed days from sustaining the injury, to return to full participation (Fuller *et al.,* 2006). Observing sports in general, Pakkari *et al.,* (2012) and Åman *et al.,* (2015) concluded that athletes at higher risk of injury are commonly practicing contact sports, combat sports and extreme sports. Whereas gymnasts, swimmers and rowers were at a lower risk of injury adherence (Pons-Villanueva *et al.,* 2010; Karlson, 2012).

Rowing-Specific Injuries

Although rowing is characterised as a low-risk activity in comparison to other sports (Junge *et al.,* 2009), due to the nature of rowing being a repetitive cyclic sport (Calvo *et al.,* 2020), research by Clay *et al.,* (2016) attributed 45% of complaints to overuse injuries. This is due to a number of factors such as muscular fatigue (Caldwell *et al.,* 2003) and repetitive performances of inadequate technique (Funder, 2005). This is supported by Pelham and colleagues (2001), who reported a high prevalence of musculoskeletal injuries specific to rowers. Further work by Clay *et al.,* (2016) suggested that rowing practice demonstrates high volumes of flexion, rotation, and hyperextension, placing athletes at a higher risk of injury. Water-based rowing is not solely responsible for injury reports, as research focuses on indoor rowing ergometer training, and other forms of cross training as factors for injury exposure (Teitz *et al.,* 2002; NG *et al.,* 2008; Wilson *et al.,* 2010). This research highlighted that inappropriate sequencing practices on the ergometer was linked to limited experience and the volume of training load (Wilson *et al.,* 2014), which had the potential to place athletes at a greater risk of injury.

It is important not to overcomplicate exposures, Finch and Cook (2014) noted that simplifying surveillance data comes with categorising injuries effectively, to prevent under-reporting or overestimating injuries. For example, identifying an injury as recurrent establishes a pattern where there is a continuation of the same injury occurring and healing; avoiding several reports of the same injury to be made (Bahr, 2009). Correspondingly, Balderrama (2019) reported that abrasions are so common in rowing, that only in extreme cases should this be reported, otherwise injury documentation would be substantial, and principally irrelevant. Upon further glace, reporting of rowing injuries contrasts extensively in relation to sample age, gender split, years of experience and size of sample. Whereas study experience is limited to elite and collegiate level, with limited attention given to non-elite junior and master rowers (Karlson, 2012). Study designs are primarily retrospective and cross-correlational systematic reviews of existing research, with findings consistently analysing similar factors such as location of injuries, type, exposure, and time loss from training as demonstrated below (see **Table 1**).

Table 1: Adult Rowers Injury Surveillance Data from Published Research (1984-2020).

Study	Sample	Study Design	Findings
Arend *et al.*, (2016)	Males (n=40), age (26.1±8.8), height (186.5±6.6), body mass (84.1±10.6), years of rowing (5.6±2.3), weekly hours trained (7.55±0.9). Females (n=38), age (22.8±7.0), height (173.3±6.3), body mass (69.3±7.9), years of rowing (4.2±2.2), weekly training hours (8.0±1.0).	Single questionnaire self-reported measures of quantitative and qualitative data.	Lifetime prevalence was high in both genders (90% and 93%, respectively), and the reported point prevalence of LBP was 10% in males and 21.1% in females. Female rowers reported significantly higher LBP intensity when training 7–16 hours per week (p=0.02), when compared to females whose training volume was less than 6 hours per week. LBP associated with long rowing workouts, weight training and long periods of sitting. LBP highly prevalent, more so in female rowers when training loads increased.
Arumugam *et al.*, (2020)	38 literature reports across a span of rowers.	Systematic review carried out.	Lumbar spine most injured site (up to 53%), followed by rib cage (9–10%) and shoulders. Rowers with a trunk-driven rowing action have a lower hip to trunk score and carry a higher injury risk. Rowers with lumbar injuries take a minimum of 3–4 months to recover.
Beijsterveldt *et al.*, (2015)	Novice rowers of 5 Dutch student rowing clubs, in total 137 freshman rowers (63% men, 37% women; mean age 20.4± 1,5 years).	Prospective questionnaires over 7 months.	3122 questionnaires were filled in during the season (mean = 23, median = 26, range 1-34 per rower). Rowers trained > 7 hours per week, mean intensity of rowing assessed as "somewhat hard – hard", 14 on a scale of 6 – 20 (= Rate of Perceived Exertion). Injuries and illnesses were the most prevalent types of these health problems (56% and 31% respectively). 80% of rowers (n=109) sustained 1 (or more) injuries during the season. The most common injury locations were knee (30%) and lower back (17%).

Bernardes *et al.*, (2015)	Senior male and female rowers in the 2013-2014 sprint and endurance Portuguese National Championships. 92 responses obtained from the 95 eligible rowers: Females (n=15) and males 9n=77).	Retrospective questionnaire over a competitive rowers' lifespan.	Mean age of first injury was significantly lower in females ($p < 0.001$). Most frequent location and type of injury were lumbar region and muscular pathology, higher occurrence in winter and spring, during land training. Females sustained longer periods of inactivity. Female rowers also had significantly more competitive-related injuries than male rowers (24%, 95% CI: 11.5 – 43.4% versus 4.2%, 95% CI: 1.8 – 9.4%). Female rowers reported a higher frequency of chronic (68.4%, 95% CI: 46.0 – 84.6%) than acute onset injuries (31.6%, 95% CI: 15.4 – 54.0%), with no differences found in male rowers. LBP (33.3 and 31.8%) most frequent anatomical location and muscle strains (29.2 and 27.2%) the most frequent type of injury occurring in female and male rowers, respectively. Most treatments were medical, although there was a non-significant tendency to injury-related longer treatment duration (21 versus 14 days), time off training (14 versus 7 days) and conditioning training (30 versus 14 days) in female rowers. Heavy athletes showed a higher risk of injury than lightweight athletes (90%, 95% CI: 77% - 96% versus 43%, 95% CI: 30 - 57%).
Boykin *et al.*, (2013)	18 rowers with a mean patient age of 18.5 years (range, 14–23 years). 85% were female and the series included prep school (44%) and collegiate rowers (56%).	Systematic review from 2003-2010.	71% had isolated groin pain and findings consistent with impingement (81%). No single, dominant location for labral tears. 18 patients who had surgery, 10 (56%) returned to rowing, 6 (33%) never returned, and return data were not available for 2 (11%) at a mean of 8 months (range, 3–25 months) after surgery.
Christiansen and Kanstrup, (1997)	Denmark national elite rowing team.	Physiological laboratory study.	5 cases of chest pain and 1 case of shoulder injury reported. Diagnosed RSF from bone scans. In all cases, an increase or alteration in physical activity in the weeks prior to the injury and an increase in specific rowing movements with special emphasis on the new equipment, combined with increased biomechanical stress applied to the thoracic skeleton in the catch and the early part of the drive phase of the stroke, most probably caused the injuries.

Clay *et al.*, (2016)	37 division I female collegiate rowers (33 rowers and 4 coxswains).	Prospective cohort study within clinical setting over one rowing season.	Those in the high-risk group were significantly more likely to experience LBP during the season (p=.036) and reported a 58% greater mean in years of rowing experience (p=.008) than individuals in the low-risk group. Those with a history of LBP were six times more likely to experience LBP during season (p=.027).
Finlay *et al.*, (2020)	160 amateur rowing club rowers; males (n=75) and females (n=85). Split by lightweight and open weight. Lightweight females; age 39.9 ± 15.2, height 166.5 ± 6.1, weight 60.5 ± 5.7. Lightweight men; age 37.6 ± 20.1, height 179.6 ± 6.5, weight 71.4 ± 3.9. Open weight females: age 37.0 ± 15.2, height 170.3 ± 6.8, weight 69.2 ± 9.7. Open weight males: age 48.3 ± 17.8, height 184.0 ± 7.5 and weight 85.9 ± 16.3.	Retrospective cross-sectional study. Looked at participant characteristics and injury information in the previous 12 months from those training/competing until March/April 2018.	Injury rate was 5.7 per 1000 sessions, with no effect of sex (χ^2 = 0.195, P = 0.659) or weight class (χ^2 = 0.800, P = 0.371). The lower-back demonstrated an epidemiological incidence proportion (IP) of 0.39 (95%CI = 0.33 to 0.46). The IP for water- and land-based training was 0.39 (95%CI = 0.31 to 0.47) and 0.57 (95%CI = 0.49 to 0.65), respectively. IP was highest between January and March (0.13–0.15), whilst time loss was 0.49 (95%CI = 0.42–0.57). The IP for ‘overuse’ and ‘traumatic’ injuries was 0.71 (95%CI = 0.65 to 0.78) and 0.22 (95%CI = 0.16 to 0.27), respectively. Training volume was positively associated with injury rate (r = 0.418, P < 0.001). Injury rates appear higher among amateur rowers with the most common injury site being the lower-back. Factors influencing injury risk included seasonal phase, training type and training volume.
Foss *et al.*, (2012)	173 former rowers.	Cohort study over 10 years.	Rowers reported frequent LBP in the past year (adjusted OR = 2.32; CI, 1.02-5.28). Occupational changes due to LBP were reported more often by rowers (13%). More rowers reported having received outpatient medical assistance. Training volume >550 h/y was a risk factor for reporting LBP during the previous 12 months compared with a training volume <200 h/y (adjusted OR =

			2.51; CI, 1.26-5.02). A previous episode with LBP was associated with LBP later in life (adjusted OR = 3.02; CI, 2.22-4.10).
Gonzalez *et al.,* (2018)	35 National Collegiate Athletic Association Division I, female, open-weight rowers (age=19.7 ±1.5 years, height=175.6 ±7.9 cm, mass=71.8± 15.1 kg, rowing experience=5.2±2.5 years). Four coxswains were not included, leaving 31 participants.	Prospective cohort study within athletic training room at start of rowing season.	18 rowers sustained LBP injury. No differences in FMS or impairments between groups. The FMS receiver operating characteristic curve analysis cut off score was 16 points (area under the curve = 0.60, specificity = 0.67, risk ratio = 1.4 [95% confidence interval = 0.91, 2.11]). Rowers with an FMS score ≤16 had a shorter plank-test time (109.5 ± 60.2 seconds) than those with less risk (175.3 ± 98.6 seconds, mean difference = 65.9 seconds, 95% confidence interval = −129.4, −2.3; P = .043).
Harris *et al.*, (2020)	Australian Rowing Team 151 elite rowers.	Analysis of prospectively recorded medical records from 2013-2015, a cohort study.	19 rib stress injuries identified amongst 12 females 7 males, 11 open weights, 8 lightweights, 12 sculls and 7 sweep cases. Most common were mid-axillary line and rib 6. Period prevalence varied from 4% to 15.4% and incidence ranged from 0.27 to 0.13 per 1000 athlete days. There were no significant differences in prevalence by sex, sweep vs scull or weight class. Statistically significant increase in incidence in the pre-Olympic year (2015, p<0.001). Stress fracture resulted in median 69 (IQR 56–157) and bone stress reaction resulted in 57 (IQR 45–78) days lost to full on water training. Time lost (median ~10 weeks) was greater than previously published literature.
Hickey *et al.,* (1997)	Elite rowers.	Retrospective analysis of injuries over 10 years (1985-1994).	Significant incidence of chest injuries, RSF, and LBP, and a high number of injuries occurring outside specific training. Elite rowers have little risk of major injury, but mild and moderate injuries are common.

Hosea and Hannafin, (2012)	Data from PubMed and textbooks.	Systematic review of existing literature.	Rowing injuries primarily overuse. The knee, lumbar spine, and ribs are most affected. The injury incidence directly related to the volume of training and technique.
Howell, (1984)	17 elite lightweight female rowers.	Incidence questionnaire	Elite lightweight female rowers had higher incidence of LBP and discomfort. 75% sample demonstrated hyperflexion of lumbar spine correlating with LBP incidence. High negative correlation between adherence to a regular stretching program and incidence of LBP.
Karlson, (1998)	10 elite rowers.	Case series retrospective review.	Fractures occurred on the antero- to posterolateral aspects of ribs 5 through 9 and were most often associated with long-distance training and heavy load per stroke.
Magrini and Striano, (2018)	405 surveys from 19 states. 62.9% female, 32.1% male. 174 athletes (46.9%) began rowing in college, 65 athletes (60.0%) were first-year rowers.	6-week surveillance self-reporting survey.	77.3% of athletes identified having sustained an injury during their rowing career. 60% of first year rowers reported having already been injured. Ergo most common etiology with 108 injuries (49.5%). 15 different bodily areas reported to have sustained injury with back being the most common (93, 42.1%) followed by knee (25, 11.3%), Rib (22, 10.0%), Hip (21, 9.5%), and Shoulder (19, 8.6%). Back injuries closely related daily volume of training. Significantly higher rates of back injuries at high training volumes, compared to other types of injury ($p=0.02$). Injuries had significant impact with 118 (53.4%) resulting in at least 1 week missed from training.
Martinez-Valdes *et al.*, (2019)	Asymptomatic rowers ($N = 10$) and rowers with a recent history of LBP ($N = 8$).	Cross sectional study of 7 × 4-minutes of exercise bouts until volitional exhaustion.	As the load increased, rowers with LBP showed higher amplitude ($p < 0.01$) and less complexity (entropy) of the HDEMG signals ($p < 0.001$). In addition, rowers with LBP showed opposite displacements of the barycenter, specifically showing a caudal shift of muscle activity at high intensities ($p < 0.001$).
McDonnell *et al.*, (2012)	Review of 9 books, 140 journal articles, 5 conferences and 2	Epidemiology review.	RSF occurs in 8.1-16.4% of elite rowers, 2% of university rowers and 1% of junior elite rowers. Approximately 86% of rowing RSF cases with known locations occur in ribs 4-8, mostly along the anterolateral/lateral rib cage. Elite rowers are more likely to experience RSF than nonelite rowers. Injury

	unpublished presentations.		occurrence is equal among sweep rowers and scullers, but the regional location of the injury differs.
Moon *et al.*, (2012)	145 rowers: male (n=84) and female (m=61).	Epidemiologic study, retrospective questionnaire survey	100 (69.0%) rowers had a history of injury. The incidence of overuse injuries significantly higher than traumatic injuries (2.07±2.59/rower vs. 1.46±2.08/rower, p=0.027). The incidence of adult injuries significantly higher than juniors (4.42±4.45/rower vs. 2.61±3.63/rower, p=0.008). No significant difference between males and females (3.85±4.33/rower vs. 3.08±3.87/rower, p=0.275). Incidence of cross-training related injury was significantly higher in traumatic injuries rather than in overuse injuries (0.92±1.54/rower vs. 0.5±1.07/rower, p=0.008). Rowing injuries were related with overuse injuries. Risk factors regarding overall rowing injuries were training time and training using stairs. Traumatic injuries were related with diverse cross-training and time spent cross-training.
Murphy (2009)	Analysis of 1100 GB elite rowers' trials.	Assessment of longitudinal training: series of pilot studies and experimental methodologies.	Adopting a kyphotic posture in lumbar spine in the rowing stroke was linked to an increased risk of lumbar injury. Rapid extension of the lumbar spine thought to pose an injury risk. The kinematic characteristics of the lower limbs may positively influence rowers' performance and provide protection against spinal injury.
Newlands et al., (2015)	76 New Zealand rowers, including 46 men (mean age 22, SD=4) and 30 women (mean age 21, SD=4).	Prospective cohort study, data collected using online questionnaire repeated monthly for 12 months.	LBP prevalence ranged from 6% to 25% throughout year. Incidence of LBP was 1.67 per 1000 exposure-hours. Total of 72 episodes of LBP reported by 40 rowers (53%) for 12 months. Of these, 45% had an incidental effect on training. 29% minor, 18% moderate and 9% had a major effect as determined by the length of time the training was interrupted. High correlation between new LBP and total training hours monthly (r=0.83, p<0.01). History of LBP risk factor in developing new LBP (OR 2.06, 95% CI 1.22 to 3.48, p=0.01). Age identified as a risk factor; likelihood of developing LBP increasing for every year (OR 1.08, 95% CI 1.01 to 1.15, p=0.02).

O'Kane *et al.*, (2003)	1829 former intercollegiate rowers.	Retrospective survey.	Those with preexisting back pain developed back pain during their college rowing career than subjects without preexisting back pain (57.1% versus 36.6%). Of those with preexisting pain, 55% missed practice as a result and 8% ended their college rowing careers. For those without preexisting pain, the percentages were 62% and 17%, respectively. For subjects with pain before their college rowing career, 78.8% missed less than 1 week and 5.9% missed more than 1 month. For subjects with no preexisting pain, 61.9% missed less than 1 week and 18.1% missed more than 1 month.
Pelham *et al.*, (2001)	8 rowers ranging from novice to Olympic standard; males (n=5) and females (n=3).	Structured interview case series.	High prevalence of specific musculoskeletal injuries in rowing. Typical injuries included: lumbar and thoracic back pain, stress fracture of the ninth rib, chondromalacia of the patella and extensor tenosynovitis of the forearm.
Penichet-Tomás *et al.*, (2012)	79 male rowers, with a mean age of 27.66 ± 7.15 (16 to 48 years old), participating in Spanish Mediterranean Bank Fixed Championship.	Retrospective questionnaire.	The anatomical regions of injury were ankle (15.4%) and lower back (13.2%). These injuries have occurred with higher incidence in training (55.1%). The most common injury is the overuse (44.2%) and the most repeated diagnosis was sprain (23.1%).
Perera and Ariyasinghe, (2916)	Healthy rowers in the Sri Lanka army sports unit (n=46) The mean age of male and female rowers was 23.7+3.03 and 23.43+2.10 years. Males (n=32) and females (n=14).	Convenience sampling for cross-correlational study of physical fitness in relation to injury rates.	Prevalence of injury which was 68.8% and 57.1% in male and female rowers respectively. The type of injury observed for male and female rowers were LBP (37.5%,21.4%), knee pain (12.5%,14.2%), hand and wrist pain (3.1%,7.1%), hip pain (0.0%,14.2%), shoulder pain (12.5%,0.0%) and ankle pain (3.1%,0.0%) respectively.

Sekine *et al.*, (2014)	68 collegiate rowers.	Cross-sectional study over two years.	31 (45.6%) rowers had disc degeneration: 48.8% of male rowers and 40.0% of female rowers. After 2 years, disc degeneration progression was observed in 5 (25%) rowers. During the 2 years, 6 rowers reported LBP. In the LBP group, disc degeneration progression was observed in 4 (66.7%) rowers. Significantly more participants in the LBP group than in the non-LBP group (7.1%) (p = 0.014) showed disc degeneration progression. The prevalence of disc degeneration among collegiate rowers was 45.6%, high at the level of the lower lumbar spine. Progression of lumbar disc degeneration was observed in significantly more LBP than non-LBP rowers during the longitudinal study.
Smoljanovic *et al.*, (2015)	634 rowers (33 % female, 67 % male).	12-month self-reporting retrospective questionnaire.	Mean injury rate 1 year was 0.92 injuries per rower (1.75 injuries per 1,000 training sessions per rower). Majority were chronic injuries (acute vs chronic ratio 1:2.63), and majority of reported injuries did not result in loss of time from training or competition. Of all acute injuries, 58.1 % were sustained during rowing-specific training, with 20.6 % injuries sustained in the gym and 21.3 % during cross-training. Most common site of injury was the lower back followed by the knee and the chest/thoracic spine.
Smoljanovic *et al.*, (2015)	1775 rowers from 70 countries participating at the 2007 Junior, Senior and Master World Rowing Championships.	Retrospective questionnaire.	812 reported a total of 1343 injuries with 935 injuries related to a chronic or overuse injury. LBP most frequent complaint and a high incidence of chronic injuries were associated with increased average number of rowing sessions. Acute injuries (n= 398) less frequent compared to chronic injuries and majority were acquired during on-water rowing specific training. Indoor rowing training such as gym and weightlifting in addition to rowing ergometer training were associated to less frequent injuries. The risk of injury was calculated to 1.75 and 2.25 injuries/1000 training sessions.
Smoljanovic *et al.*, (2018)	743 master's rowers participating in International Federation of Rowing Associations 2007.	Cross-sectional study questionnaire followed by interview 12 months before competition.	Mean injury rate per year was 0.48 injuries/masters' rower (2.25 injuries/1000 training sessions/rower). Most injuries were chronic (the ratio of acute to chronic injuries was 1:1.7) and did not lead to loss of training/competition time. Of all acute injuries, 49.6% were acquired during rowing-specific training, 43.7%

			during cross-training, and 6.7% in the gym. The most was LBP (32.6%), followed by the knee (14.2%), shoulder/upper arm, and elbow (10.6% each).
Socratis *et al.,* (2013)	211 Greek rowers; males (n=156) and females (n=55) over many ages competing to a high level.	Self-reporting questionnaire over two-year period.	Most common injury site in men was the lumbar area (46.7%) then knee (18.6%); while for adult and junior females was the lower back (29.1% and 29.4% respectively), then the knee (28.6% and 11.8%) and the elbow (7.1% and 11.8%). In junior males, the lower back had the greatest incidence (12%). Seniors presented mainly lower back injuries (35%). Both genders reported training on land (in the gym) as the risk factor most significantly associated with injury.
Teitz *et al.,* (2002)	1632 former intercollegiate rowing athletes.	Retrospective surveys.	526 reported back pain for longer than 1 week during their time as an intercollegiate rower. Factors associated with development of injury were age, free weight training, history of rowing before aged 16 and ergometer training. Back pain while in college also was associated with higher mean college weight and height.
Trease *et al.,* (2020)	153 Australian international-level rowers selected.	Monitoring under surveillance for injury and illness over 8 seasons between 2009-2016.	270 injuries occurred with an incidence of 4.1–6.4 injuries per 1000 AD (per 1000 days). Training days lost totalled 4522 (9.2% AD). Most frequent area injured was lumbar region (84 cases, 1.7% AD) greatest burden was from chest wall injuries (64 cases, 2.6% AD.) Overuse injuries (n=224, 83%) more frequent than acute injuries (n=42, 15%). Activity associated with injury was water rowing training (n=191, 68). Female rowers were at 1.4x the relative risk of chest wall injuries than males; they had half the relative risk of lumbar injuries of male rowers.
Trompeter *et al.,* (2019)	156 rowers (104 elite and 52 non-elite/ 49 scull and 76 sweep rowers) and 166 controls (n=221).	Cross-sectional study, standardised LBP questionnaire.	Back pain prevalence and severity was significantly higher amongst rowers compared to controls, and amongst scullers compared with sweep rowers. Lumbar spine main location of back pain in rowers of all competition levels and in controls. Age, sex, and training volume influenced the prevalence of back pain. Rowing kinematics, strength, and ergometer training were the main associated risk factors for back pain in rowers.

Verrall and Darcey, (2014)	National (n=45) and international (n=12) rowers on the South Australian Sports Institute Program.	Retrospective analysis of medical and screened records of rowers.	Cohort of national rowers had 15 lower back injuries compared to 1 injury report from international rowers. A national level rower was more likely to have a lower back injury compared to an international rower (P = 0.05). In contrast an international level was more likely to have a RSF compared to a national rower (P = 0.04).
Wilson *et al.*, (2010)	20 international rowers competing for Irish Amateur Rowing Union.	Prospective cohort study over 12-month period intervened monthly.	Mean injury rate of 3.67 per 1000 exposure hours reported, total of 44 injuries over 12-months. Mean number of injuries sustained per athlete was 2.2 (1.24) over 12-months. Most injuries in lumbar spine (31.82% of total injuries, 95% CI 20 to 50) knee (15.91% of total injuries, 95% CI 10 to 30) and cervical spine (11.36% of total injuries, 95% CI 5 to 24). Half of the injuries (22 injuries, 50% of total reported injuries) were to the spine (χ^2 = 30.8, df = 9, p = 0.0003). Ergometer training load was the most significantly associated with injury risk (r = 0.68, p = 0.01).
Wilson *et al.*, (2014)	Series of rowing studies.	Epidemiology and biomechanical analyses.	Studies that reported 12-month data, incidence of LBP ranged from 31.8 to 51% of the cohort. Of the limited studies that specifically examined LBP in rowers, history of lumbar spine injury and volume of ergometer training were the most significant risk factors for injury onset.
Winzen *et al.*, (2011)	29 female rowers aged 22.2 ± 3.1 years and 38 male rowers aged 22.3 ± 3.1 years on German national team.	Prospective and retrospective interviews.	Rowers trained on average 22.8 ± 5.3 hours in 16.0 ± 4.6 training sessions per week. The most frequently reported injuries during the 12-month period were at the lumbar spine/buttock (50.0 % of interviewees), followed by the shoulder girdle (33.9 %), the forearm/hand (32.2 %), the cervical spine (31.6 %) and the thoracic spine (28.1 %). The most frequently reported reason for injuries was" overuse" in all regions.

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Common Sites and Types of Injuries in Rowers

LBP within the lumbar region has been identified as the main site of injury for rowers (Ceccato *et al.,* 2014) **(Table 1)**. Other common sites of injury include the shoulders (Winzen *et al.,* 2011), knees (Karlson, 2000; Wilson *et al.,* 2010), RSF (Verrall and Darcey, 2014), hip impingements (Boykin *et al.,* 2013) and wrists (Pelham *et al.,* 2001; Smoljanovic *et al.,* 2009). Furthermore, the identifiable areas at risk of injury are consistent across all ages, genders, and performance levels (McNally *et al.,* 2005; Karantanas, 2010; Baugh and Kerr, 2016) **(Table 1)**.

Lower Back Pain

Injury research into rowing dates back to 1958, where Lloyd reported backache in Commonwealth Games rowers, which has collated within the last 30-years, extensively uncovering LBP as the most identifiable site for injury (Sekine *et al.,* 2014); acknowledging 30-50% of rowers to have experienced back pain at some point during their rowing career (Wilson, 2016). The lumbar vertebrae supports and transfers the force applied during the stroke from the catch through to the finish, which can predispose to LBP (Retailleau *et al.,* 2017). This is reflected in the work of Hosea and Hannafin (2012), who reported that the general sequence of the rowing stroke exhibits undue stress through the lumbar spine. Supporting research by Reid and McNair (2000) and Caudwell *et al.,* (2003) reported that rowers during training display high levels of lumbar flexion at the front end of the stroke. This can be applied to the physiological differences between land and water-based rowing, where Kleshnev (2005) reported a 3-5% increase in stroke length on the ergometer through increased lumbar flexion, in turn increasing risk of injury attainment from overloading the spine during the stroke. Moreover, Wilson *et al.,* (2013) reported a higher percentile range of motion, to 11.3% flexion on an ergometer, to 4.1% lumbar reach on-water. Whilst the catch and drive are already a threat to sustaining LBP, Kleshnev (2016) recognised a further complication of catching the stroke whilst demonstrating a flexed spine. Excessively performing under hyperflexion can initiate longer-term injuries from onset of LBP, to spondylolysis, sacroiliac joint dysfunction, and disc herniation (Rumball *et al.,* 2012).

As research interest is growing within sports injuries and rehabilitation, it is becoming more feasible to pre-empt those who are at a higher risk of sustaining injuries within specific sports, and therefore implementing preventative measure to minimise such risks (Thornton *et al.,* 2016). Work by Newlands and colleagues (2015) reported an increased risk to LBP positively correlated with total training hours per month. Equally, Clay *et al.,* (2016) also identified experienced rowers to be at an increased risk of LBP due to higher and longer exposure to the sport. Length of time training and risk of injury exposure connect with the risk of reoccurring injuries. This results in possessing LBP, therefore significantly increasing the risk of redeveloping a back injury at a later date (Newlands, 2013). Application of this is recognised in research by Wilson *et al.,* (2014), who found that LBP was commonly developed in head season periods within winter months; which directly linked with the changes in length of training sessions preparing for head races; most prominent when sessions exceed thirty minutes, as opposed to shorter interval training within summer months (Wilson *et al.,* 2008). November through to January are the key months where injuries are reported, given the increase in land training and resistance sessions associated with indoor rowing (Wilson *et al.,* 2010).

Another cohort with limiting research yet posing an increased threat to lumbar-related injuries are junior rowers: NG *et al.,* (2014) reported that out of 365 14-16-year-old rowers, 64% of boys reported LBP, to 52% of females. High exposure to long distance aerobic ergometers and engaging in free weights before the age of sixteen, are just two potential structural factors that place juniors at a higher exposure risk (Teitz *et al.,* 2002). Similar to adult rowers, long distance rowing results in a breakdown of technique over time due to fatigue, which is more likely to onset earlier in junior athletes (Holt *et al.,* 2003). Research by Steinacker *et al.,* (2000) supported this theory, analysing training in elite junior rowers. Results exhibited that fatigue and overtraining were associated with overreaching at the catch; hyper-flexing the lower back therefore overloading the lumbar spine and increasing risk of LBP. However, research in this area is dated, and explicitly focused on elite juniors as opposed to grassroot club members (Hickey *et al.,* 1997), therefore a more inclusive project is required to fully identify potential risks.

Knees

Knee pain and associated injuries are the second highest reported site of injury in rowers across research (Smoljanovic *et al.,* 2009; Maurer *et al.,* 2010; Wilson *et al.,* 2010). Despite patellofemoral complaints significantly arising within rowing injury surveillance documents (Finlay *et al.,* 2020), the limited evidence provided is heavily focused on abnormal patellar tracking alongside noted flexibility complications and skill acquisition aggravation (Rumball *et al.,* 2012). Rowing as a continuous sport repetitively loads and unloads the patellofemoral joint (Chimera and Kremer, 2016), placing undue stress through the articulation resulting in inflammation and thereon retro-patellar pain (Rumball *et al.,* 2012); causing sports-related injuries such as Iliotibial Band (ITB) friction and chondromalacia patella (Hosea and Hannafin, 2012). The three key muscle groups supporting the knee joint, and therefore having an impact on patellar pain if improperly flexible are the quadriceps, hip flexors, and the IT band (Hosea and Hannafin, 2012). A decrease in suppleness within any of these areas significantly impacts the placement of the knee by increasing the resistance, therefore reducing range of motion around the joint (Wilson, 2020), causing strain to the ligaments when reaching the catch position and aggravating the articulation.

Knee pain is also an associated secondary injury from overreaching through the lumbar spine at the catch, over-compressing the knee joint (Davenport, 2017). Reaching further forces the body into a weak position, thereby catching the stroke ineffectively with danger of injury to both the lower back and knees (Karlson, 1999). This is through placing substantial weight on the stern of the boat, transferred through to the surrounding patellar ligaments. Minor modifications to the boat arrangement can also have detrimental effects on knee position at the catch by modifying the flexion angle (Hosea and Hannafin, 2012). Furthermore, tactical skills such as steering are believed to be linked with knee injury reports, aggravating the joint through foot positioning whilst exhibiting maximal force through the leg drive (Bartlett and Warren, 2002). However, current research into steering-related injuries as well as boat structure complications are limited, and only beginning to be identified to fully explore the potential injuries in this area (O'Connor, 2020).

Ribs

Research by Hosea and Hannafin (2012) reported that off-water training including strength and conditioning or simulated outdoor rowing equipment predisposes athletes to RSF. Contrary work by Holden and Jackson (1985) report that inadequate strength and conditioning practice increases a rowers' susceptibility to RSF. This is under the pretences that the programme is too strenuous for the underage rower, or the improper technique is adopted. Nevertheless, the two studies are tied to the work of Thornton *et al.,* (2016), who reported that training load, energy deficits and lack of knowledge were key identifiers when analysing rib injuries.

RSF are also caused by compression on the ribs through pectoral and obliquus externus abdominus activation (Wajswelner and colleagues, 2000). Longer term injuries identified in rowers include costochondritis, costovertebral joint subluxation, and intercostal muscle strains (Rumball *et al.,* 2012). RSF are a problem in rowing (Warden *et al.,* 2002), due to exercise-induced fatigue and rib cage compression (Bojanić and Desnica, 1998). D'Ailly *et al.,* (2015) reported that 8-16% of rowers reported rib pain during their careers. Age is a key indicator when determining those at risk (Christiansen and Kanstrup, 1997). Undoubtedly, master's rowers are considered to be at the highest risk of rib trauma due to age-related bone degeneration including osteoporosis, in comparison to their younger counterparts (Bulger *et al.,* 2000). However, contrary to musculoskeletal considerations, McDonnell *et al.,* (2012) found that rowers aged 22-27 had the highest report of rib stress; coincidentally this bracket also covers the age of elite rowers, suggesting a relationship between workload and RSF, as opposed to age-related health decrements. Supporting this notion, work by Great Britain's Rowing Team health professionals Evans and Redgrave (2016) reported that overloading the rib shaft, in particular when engaging in poor technique or performing under increased load, places the athlete at higher risk of injury.

Hips

Hip pain and impingements are limited in research despite being linked to time out of training for rowers (Thornton *et al.,* 2016), and accounting for 9% of total injuries sustained during a rowers' career (Magrini and Striano, 2018). The hip flexors consist of the iliacus, psoas, and the rectus femoris within the quadricep, covering the hip flexor to the knee flexor (Emery *et al.*, 2019). Hip injuries present themselves as mechanical stress, as a result of repeated flexion and extension during the rowing stroke (Ruth, 2015_b) or as an injury due to flexibility limitations (Hannafin, 2011). A further implication of reduced range of motion to the hip flexor is reduced hamstring flexibility, causing anterior pelvic tilt (NG *et al.*, 2013) and drawing the hips underneath the body which can heavily restrict the drive phase and cause LBP (Cañeiro *et al.*, 2013). Additionally, hip pain is associated as a secondary injury when analysing the knee extension during the rowing stroke, as adequate range of motion within the knee joint enables full anterior rotation of the pelvis during the recovery phase (Murphy, 2009). This suggests that inadequate knee flexibility prevents the rower from exhibiting a strong catch position, thus relying on overcompensation of the hip hinge to achieve full compression of the catch (Buckeridge *et al.*, 2012). Long term side effects include femoral acetabular impingement syndrome and labral tares (Boykin *et al.*, 2013; Mottram *et al.*, 2019).

Shoulders

Shoulder pain is attributable to many factors of the rowing stroke, yet commonly lies with inadequate technique, general overuse of the surrounding muscular structure and increased upper-body tension whilst taking the stroke (Rumball *et al.*, 2005; Page *et al.*, 2012). Urbanczyk and colleagues (2019) reported that shoulder-related pain corresponded with imbalances in strength, particularly in sweep rowers; therefore, junior rowers of sweep age and above are at an increased exposure risk to shoulder injuries. The demands of the shoulder during the rowing stroke requires the scapula to retract as the humerus rises at the catch position, placing force through the shoulder to transfer the power through the handle to the legs (Parkin *et al.*, 2001), with the potential to cause injury.

Forearms and Wrists

During the rowing stroke, the blade handle rolls through the phalanges to execute the feathering and squaring motion of the blade. Blade placement relying on the wrist action can compress the extensor tenosynovitis resulting in inflammation anywhere from the elbow, to the wrist and down to the thumb (Karlson, 2000). As a result, common forearm and wrist injuries include exertional compartment syndrome, intersection syndrome and lateral epicondylitis (Midgley, 2018); all can be triggered by fatigue from the feathering motion and excessively tight grip on the handle (Thornton *et al.*, 2016). However, the rowing stroke does not always account for the forearm and wrist injuries, but instead can result from improper handle sizes, cold and wet weather, or incorrect rigging (Rumball *et al.*, 2005), initiating over-gripping.

Skin Abrasions

It is important to note that although it is not considered a recognised injury in all surveillance data and the research database, abrasions are commonly experienced by rowers of all ages and experiences. All rowers will acknowledge blistering of the hands across the inner thumb and the skin that runs across the metacarpals at some point during their rowing career. This is often a result of strength and conditioning bars, ergometers handles and blade handles (Karlson, 2000). This is caused from excessive friction, particularly if a rower is gripping tightly (Hannafin, 2011), and if not treated correctly can lead to infection (Rumball *et al.*, 2012). Another common hand abrasion from rowing is 'sculling knuckles' (Hartz and Lang, 2016). This is another friction-related injury, where the left hand crosses the right hand at the back end of the stroke; the rowers' fingertips or nails cross over the right hand's knuckles, causing redness and in some cases, bleeding (Kramer and Wilson, 2016). The final common skin abrasion rowers regularly experience is known as 'slide bite', which is where the runners on the saxboard of the boat repeatedly scratches a rower's calves (Tlougan *et al.*, 2010). This is a result of an incorrectly set-up boat, sharp slides, and improper calf protection (Volpenhein, 2019). Again, although abrasions are not serious, they must be treated to avoid infection.

Acute vs Chronic Injuries

Defining sports injuries, or illnesses can be categorised as acute or chronic depending on the treatment required and length of treatment time (Whitlock, 2020). Acute injuries are defined as one-off traumatic events instigating the injury (Lavallee and Tucker, 2010), whereas chronic injuries are a result of repetitive microtraumas over time, often referred to as overuse injuries (Raske and Norlin, 2002). Further diagnostic criteria developed by Yang *et al.,* (2012) identified acute injuries as dislocations, fractures and open wounds, and chronic injuries as impingements and inflammations. A significant proportion of self-reported injuries are categorised as chronic overuse as opposed to acute onset (Smoljanovic *et al.,* 2015), Moreover, Smoljanovic *et al.,* (2009) reported 73% of injuries as overuse within 398 rowers' reports. Both studies support current literature that holds chronic overuse injuries responsible for the majority of rowing injuries (Bovee, 2015; Ruddick *et al.,* 2019). Moreover, Gosheger *et al.,* (2003) generalised that non-contact sports such as rowing had higher reporting of overuse chronic injuries as opposed to acute.

Junior Injury Surveillance

Table 2: Junior Rower Injury Surveillance Data Published Research from 2010-2020.

Study	Sample	Study Design	Findings
Bellarmine University (2010)	High school rowers (n=24), males (n=11) and females (n=13). Members of Louisville Rowing Club. (Age = 16 ± 2). Years of rowing 2-36 months.	Pilot study of data collection survey.	18/24 rowers experienced LBP before. 19 had been rowing for <1 year. 6 reported an injury other than LBP. 4 reported knee pain, 1 reported elbow pain, and 1 reported hip flexor injury. In LBP athletes, >50% sweep rowed. 22/23 of those who had LBP stated their pain was a 5 or less on the visual analog scale. Approximately 80% of the rowers participated in training/ practice 5-8 hours per week.
Boykin *et al.*, (2013)	18 rowers mean patient age of 18.5 years (range 14–23). 85% female including prep school (44%) and collegiate rowers (56%)	Systematic review from 2003-2010.	71% had isolated groin pain and findings consistent with impingement (81%). No single, dominant location for labral tears. 18 patients who had surgery, 10 (56%) returned to rowing, 6 (33%) never returned, and return data were not available for 2 (11%) at a mean of 8 months (range, 3–25 months) after surgery. It is important to note that this study exhibits both junior and senior rowers.
Caldwell *et al.*, (2003)	16 school rowers.	Cross-sectional repeated measures design during a rowing trial.	Excessive lumbar flexion may influence the potential for injury to spinal structures. An awareness of increased lumbar flexion and muscle fatigue in the erector spinae muscles may be important for injury prevention programs for rowers.
Funder, (2005)	Senior schoolgirls from 7 Melbourne Girls schools from 2004-2005 (n=186).	Retrospective study surveys.	Rowing caused the highest number of injuries (48%), ergometers (21%), running (14%), weights (12%). Rowing technique when fatigued can cause injuries.

Maurer *et al.*, (2011)	44 asymptomatic adolescent boys distributed in 2 groups of 22 rowers and 22 control subjects.	Cohort study, MRI and prevalence data.	9 rowers (40.9%) had at least 1 abnormality detected by MRI in lumbar spine, only 2 participants (9.1%) in control group had at least 1 MRI abnormality (P = .03). 7-disc changes (31.8%) and 6 pars abnormalities (27.3%) found in elite rowers. In the control group, 3-disc changes (13.6%) and no abnormalities found in MRI scans. Disc disease and pars interarticularis stress reaction are prevalent abnormalities of the lumbar spine of high-performance rowers.
NG *et al.*, (2008)	22 rowers: females (n=12) and males (n=10) aged 14-17 with and without LBP.	Mechanical aetiology of clinical testing and subjective pain evaluation.	Gradual increase in LBP experienced by the LBP group during 20-min ergo trial. 2 rowers (1 male, 1 female) ceased testing after 15-minutes of the rowing trial as level of pain exceeded that of normal training. 1 subject in LBP group did not report pain during but reported pain the next day. Rowers with LBP spent longer in flexion compared to those without LBP during the drive phase (p=0.025). Rowers with LBP spent a greater proportion of time during the drive phase near end range of lumbar spine flexion (above 90% of full flexion) (p=0.026).
NG *et al.*, (2014)	Adolescent male rowers (n=130) and females (n=235) aged 14-16.	Retrospective cross-sectional survey.	High lifetime and point prevalence of LBP found in both adolescent male (93.8% and 64.6%, respectively) and female (77.9% and 52.8%, respectively) rowers. A significant between-gender difference reported for both statistics ($p < 0.001$). A significantly lower ($p = 0.003$) pain level found in males (4.1/10) compared to females (5.0/10). Similar rowing aggravations reported by males and females although fewer males reported that lifting the rowing shell aggravated their LBP.
NG *et al.*, (2015)	10 adolescent rowers with moderate levels of LBP compared to 10 rowers with no history of LBP.	Regional lumbar spinal kinematics and self-reported LBP intensity during 15-minute ergometer trial.	No significant differences detected in upper or lower lumbar angles between rowers with and without LBP. Rowers with LBP had less excursion of upper lumbar spine into extension over the drive phase; less excursion of the lower lumbar spine into extension over time; had greater variability in upper and lower lumbar angles over 15-minute ergo trial; positioned upper lumbar spine closer to end range flexion for a greater proportion of the drive phase; showed increased time in sustained flexion loading in the upper lumbar spine.
NG et al., (2015)	36 adolescent male rowers; 19 were	Randomised controlled trial	Intervention group reported significantly less pain during ergo rowing (Numeric Pain Rating Scale −2.4, p=0.008) and reduced disability (Patient Specific

	randomly allocated to the intervention group, active control group (n=17).	during 15-minute ergo trial pre- and post- intervention 12-weeks later.	Functional Scale (4.1, p=0.01); Roland Morris Disability Questionnaire (−1.7, p=0.003)) following intervention, and at 12-week follow-up. Demonstrated greater lower limb muscle endurance (20.9 s, p=0.03) and postured their lower lumbar spine in greater extension during static sitting (−9.6°, p=0.007).
Perich, (2010)	356 schoolgirl rowers and 496 age-matched non-rowers from schools involved in the schoolgirl rowing competition in Western Australia,	Cross Sectional study	Significant differences were evident in pain incidence between rowers and non-rowers for all ages. There was a significant difference in pain incidence between Year 9 and 10 rowers. Rowers showed significantly greater pain and disability scores when compared with non-rowers. A number of self-reported rowing-related and habitual factors were associated with LBP in rowers. LBP is common in schoolgirl rowers and there are several exacerbating factors that bring on or exacerbate LBP.
Perich *et al.*, (2011)	Intervention group 90 schoolgirl rowers from 1 school and control group 131 participants from 3 other schools.	Non-randomised control trial intervention program over 1 rowing season.	The intervention group had a lower incidence of LBP mid-season and end-season and displayed significantly better results than the control group.
Smoljanovic *et al.*, (2009)	398 rowers (42% female, 58% male) participating at the Junior World Rowing Championships in Beijing.	Descriptive epidemiology study, 4-page injury questionnaire.	290 (73.8%) rowers reported overuse injuries, and 103 (26.2%) were related to a single traumatic event. Female rowers were injured more frequently than males (110.2 vs 90.5 injuries per 100 rowers). Both genders, most common injury site was the lower back followed by the knee and forearm/wrist. The severity of reported injuries was incidental in 65.1%, minor in 21.4%, moderate in 10.4%, and major in 3.1% of cases. The rowers with traumatic injuries had less rowing experience than the uninjured rowers (median [C] ± interquartile range [Q] = 3 ± 3 years vs 4 ± 3 years; P = .043, Mann-Whitney test). Sweep rowers who changed side during the season had significantly more acute-onset low back injuries (P = .012, χ^2 test) than those who did not change rowing side during the same period. The incidence of traumatic injuries was significantly lower in rowers who regularly performed more than 10 minutes of post training stretching

			(P = .030, χ^2 test). Athletes who ran more than once a week had more overuse knee injuries than those who ran once or less per week (P = .033, χ^2 test).
Weerts *et al.*, (2019)	17 male adolescents.	Assessing hamstring flexibility and lumbopelvic kinematics during ergometer training.	No association found between hamstring flexibility and pelvic kinematics during rowing (RoM: P>.18, r=.35 and angle at catch: P>.48, r=.19), suggesting there is no influence of hamstring flexibility on lumbopelvic kinematics in adolescent male rowers. Therefore, techniques to increase hamstring flexibility may be ineffective in LBP prevention and rehabilitation. In contrast, years of experience showed a strong effect on lumbar RoM (P < .01, r = −.726) and a weak effect on pelvic motions (P < .04, r = .542), suggesting technical skills are more important.

2.5 Injury Severity

A common complication of defining injuries as traumatic or acute is that neither can recognise an injury's severity (Lavallee and Tucker, 2010). Reporting severity rates of injuries, Smoljanovic *et al.,* (2009) found 65.1% of injuries were incidental, minor in 21.4% of cases, 10.4% moderate and 3.1% major injuries. This supports the early work of Hickey *et al.,* (1997) who proposed that elite rowers are at a reduced risk to major injuries, but mild and moderate-severity injuries are common. Although, this only identifies elite athletes, with no acknowledgement to amateur participants. However, Smoljanovic *et al.,* (2009) identified inexperienced rowers to be at an increased risk of traumatic injuries, suggesting that further research into grassroot rowers is required. The severity of an injury can also be defined through time lost from training (Yang *et al.,* 2012). Incidental injuries can be defined as no time lost, minor for less than one week, moderate for one to three weeks, and major for time out exceeding three weeks (Bahr, 2009). Nevertheless, time out of training is subjective to athlete and coach discretion, and those who continue with an altered training programme are still participating, but not to the fullest form.

2.6 Injuries in Junior Rowers

Junior rowers commit to similar training programmes to their senior counterparts, with comparable training load and session contents, yet injury research into rowers aged <18 is limited in comparison to adult rowers (Thornton *et al.,* 2016). This is demonstrated when comparing **Table 1** and **Table 2**, there is significantly more adult rowing injury reports in contrast to junior surveillance documents, 37 to 14 studies respectively. Furthermore, comparing junior to senior injury rates have not been possible in previous research, as sample sizes and methods vary drastically between studies. However, the work of Smoljanovic *et al.,* (2015) surveyed competitors at the junior and senior World Championships, reporting junior rowers to be at an increased injury exposure risk in comparison to seniors (2.1 vs 1.75 injuries/1000 training sessions). This provides insight as to why research in this field is required, and why junior injury rates should be monitored, if further research demonstrates that juniors are at an increased risk. Furthermore, the report highlighted the training hours engaged in by rowers, recognising that inappropriate training load for juniors is a high-risk factor for injury (Bellarmine University, 2010).

Moreover, it is important to acknowledge that adapting from sculling to sweeping occurs around the pivotal age of 15-16 years old, which can make or break a junior athlete (Urbanczyk *et al.,* 2019). Work by Ruth (2015_a) reiterates biomechanical imbalances perpetrated through engaging in sweep rowing as opposed to sculling triggers movement inefficiencies, decreases performance output and most importantly, increases risk of injury. In addition to this, across both **Tables 1** and **2**, LBP and knee aggravation are the most common themes of rowing-related injuries across both junior and senior cohorts. Supporting this idea, research by Maurer *et al.,* (2010) indicated that back injuries are an extremely common complained site of injury in rowers, especially when rehabilitating juniors (Smoljanovic *et al.,* 2009). Topical research by Dodson (2019) identified three key indicators to recognise junior injury prevalence rates;

1. poor technique
2. Training hours
3. Over training

Ultimately, the location and cause of injury have been studied in comparison to training time and load, yet there is little cross-referencing to gender, age, and other individual components making the rower susceptible to injuries (Smoljanovic *et al.,* 2015).

Junior Characteristics Increasing Vulnerability to Rowing Injuries

It has been suggested that female athletes are at a greater risk of injury across sports (Lin *et al.,* 2018); particularly for overuse injuries (Smoljanovic *et al.,* 2009; Frank *et al.,* 2017). Neeru and Dugas (2017) found this was a result of early specialisation. There is also evidence for a longer time out of training as a result of injury in females (Hunt *et al.,* 2016). In rowing, female athletes appear to sustain more RSF than males (Boland and Hosea, 1991). This is supported by the work of Holden and Jackson, (1985) and Galilee-Belfer and Guskiewicz, (2000) who found that females are at an increased risk of attaining RSF, suggesting that this was due to inadequate engagement and accessibility of strength and conditioning sessions within their club programmes. This provides potential long-term scope that instilling strength training programmes across clubs for both genders, places females at a decreased risk for musculoskeletal injuries (Clay *et al.,* 2016). Clay *et al.,* (2016) compared LBP between males and females, reporting that females are at double the risk of injury in comparison to male counterparts, and males being more susceptible to traumatic one-off injuries rather than overuse. Research into providing explanation for injuries in juniors and recognised gender differences focuses on hormonal imbalances (Hansen and Kjaer, 2016), circadian rhythms and the importance of sleep on injury prevention (Copenhaver and Diamond, 2017), menstruation effects in females (Paterno *et al.,* 2013), and age-related milestones such as growth spurts (Brown *et al.,* 2017).

Hormonal changes are often accompanied by periods of rapid growth in adolescence (Storm *et al.,* 2018), triggering reduced range of motion and therefore increasing the risk of injury attainment (Wild *et al.,* 2013). Wild also identified an increase in quadricep and hamstring strength during periods of hormonal change, particularly in males; unbalancing the muscular structure surrounding the patellofemoral joint and therefore destabilising the knee, leaving it vulnerable to injuries. McKay *et al.*, (2016) hypothesised that a lag between cognitive and physiological development, coupled with pubertal hormones, places adolescent athletes at an increased risk to sports injuries. With this knowledge and considering the practical coaching element of maturing rowers, Farpour-Lambert (2020) argue that assessing athletes on an individual basis allows coaches to take into consideration hormonal imbalances and peak pubertal changes, to tailor training and competition requirements. This is encompassed within the research of Tønnessen *et al.,* (2015), who reiterated the importance of gender-specific training plans for athletes undergoing hormonal changes and growth spurts, to ensure maturation is considered when increasing performance outcomes whilst limiting injury risk. A key hormonal change within females is menarche. Menstrual disturbances may increase the risk of stress fracture in female athletes, as a reduction in production of oestradiol can lead to reductions in bone strength (Scholes *et al.,* 2002; Lappe *et al.,* 2008). Growing research in the field is exploring how menstruation and managing cycles can be beneficial to an athlete's performance, by identifying phases when female athletes are at their strongest, whilst reducing risk of injury attainment (Oleka, 2020).

Circadian rhythms are also important to consider, such as variations to the athlete's sleep cycle (Dwivedi *et al.*, 2019). Biopsychosocial barriers experienced by many teenagers and acknowledged within sleep studies when analysing irregular sleep patterns include; persistent nightmares (Bruni *et al.,* 1999); engaging in copious amounts of part-time work or extra-curricular activities (Dorofaeff and Denny, 2006); academic stressors (Chung and

Cheung, 2008); and those suffering from depression (Do *et al.,* 2013). Despite the cause of sleep deprivation, practical research by Milewski *et al.,* (2014) found a correlation between lack of sleep and sports injury rates, reporting that less than 8 hours of sleep a night increased the risk of injury (RR=2.1; 95% CI, 1.2-3.9; *P*=0.01). Dwivedi *et al.,* (2019) concluded the importance of educating athletes on sleep hygiene to minimise the risk of injury: with sleep comes increased cognitive functioning, longer recovery periods and reduced neurocognitive impairment.

Finally, when considering age-related predispositions to injury attainment, Brown *et al.,* (2017) highlighted that puberty in both females and males is a significant time for physical, developmental, and maturational changes to occur. Growth spurts are a natural physiological change, where standard spurt rates occur between 8 and 15 years old for females, and 9 and 16 for males; with girls maturing approximately 2 years before boys (Castle, 2014). Similarly, a research article published by the NHS (2018) discussed the average maturation ages of juniors; females maturing ~11 years old and males ~12 years. Growth spurts and age-related maturation are both associated with restricted muscle-tendon tightness due to bone elongation, resulting in loss of flexibility (Caine and Goodwin, 2016). Skeletal immaturity potentially links to overuse injuries in adolescent rowers, due to underdeveloped muscular and bone structures (Sando and McCambridge, 2013). In addition to this, Neeru and Dugas (2017), reported those who are specialising earlier within a sport, will experience regular complications with growth spurts, correlating positively with overuse injuries (Steina and Rozenstoka, 2016). Research therefore infers that if a coach can successfully manage an athlete's maturation in relation to training load and capabilities, injury adherence would reduce (McKay *et al.,* 2019).

How Much, How Often? How Training and Overtraining Can Cause Injuries

In line with British Rowing's long-term athlete development guide, the governing body have recognised that there are specific considerations for the developing athlete in order to prevent onset of injury and incur training benefits. In line with the 'How Much How Often?' guide by British Rowing (2019_d) represented in **Figure 2**, the document provides an outline as to why there are limitations on session contents, duration, and frequency with certain age groups; it takes into consideration puberty, physical maturation changes, educational and social considerations, and practicalities of training.

BRITISH ROWING

Rower Pathway				Advice for Rowing Specific Activity (On Land or Water)				Notes
Development Level [N1]		Requirements [N2]		Number of sessions per week [N3]		Session Length [N5]	Hours of Training per week	
				Average	Maximum [N4]			
Level 4	Competitive club rowers and those breaking into High Performance.	Rowers should complete and be competent in all pillars in levels 3, 2 & 1.	Rowers aged 17 and over.	6	8	Water <90' Land <80'	6 - 12	
Level 3	Rowers competing in national events.	Rowers should complete and be competent in all pillars in levels 2 & 1	Rowers aged 15 and over.	4	6	Water <75' Land <60'	4 - 8	J15 and under and older rowers new to strength training to be core/trunk & conditioning only.
Level 2	Developing rowers or those focusing on local events.	Rowers should complete and be competent in all pillars in levels 1.	Rowers aged 13 and over.	3	4	45' - 60'	2 - 4	Water activity for J14 and under should be sculling only. General athleticism should also be encouraged for all age groups.
Level 1	All Rowers of any age.	-	Rowers aged 11 and over.	-	2 (Skill development only)	30' - 40'	1 - 2	

Figure 2: British Rowing (2019$_d$) How Much How Often? Guide.

Exceeding the developmental level for an athlete and surpassing their requirements against British Rowing's advice can place a rower at an amplified risk of injury. Increasing the number of sessions weekly, length of sessions and hours trained per week beyond an athlete's capabilities can result in an injury, and moreover what is known as an overuse injury. The work of Smoljanovic *et al.*, (2009) identified training load as a key indicator for overuse injuries, as when sessions exceeded 7 times per week, the risk of injury significantly increased. Early literature heavily identified overtraining and overuse traumas as the main concern for rowing injuries (Hosea *et al.*, 1984; Karlson, 2000). Despite being dated, overuse injuries correspond with more contemporary research, now highlighting various training cues spurring overtraining-related injuries, including altered technique, sweeping, and sculling, training volume and ergometer use (Wilson *et al.*, 2010; Hosea and Hannafin, 2012; Wilson *et al.*, 2014). Regardless of land-based training providing performance enhancing benefits through endurance and technique, improper training programmes can rapidly overload an athlete increasing the risk of overuse injuries (Rodford, 2012$_a$; Rodford, 2013).

2.7 Study Rationale

A common complication associated with diagnosing any injury is the process of self-declaration due to the self-reporting nature of injury identification, and limited medical diagnostics; the severity of a musculoskeletal injury can be largely subjective (Gabbe *et al.,* 2003). In addition, reflecting on an injury retrospectively for research purposes complicates recall accuracy, due to combining physical pain with emotional ties to the sustained injury (Valuri *et al.,* 2005). An injury that is associated with a significant setback or causes undue stress such as effecting team selection, can cause the athlete to endure psychological pain in addition to the injury, increasing the reported severity (Barth, 2010). The majority of surveillance data into rowing injuries is retrospective (Wilson *et al.,* 2014; Newlands *et al.,* 2015). Consequentially, rowing injury reports require prospective research into junior rowing injuries, to report injury surveillance more accurately.

With this in mind, the purpose of the current research was to analyse reported injuries in junior rowers from clubs across the country. The main aim was to determine incidence and any factors relating to injury. Similar studies have already been conducted in football (Fuller *et al.,* 2006) and should be comparable to other injury surveillance reports. Current injury research in junior rowers has mainly been conducted on adult participants and outside of the UK, on international performance level athletes only. It is anticipated that through an analysis of factors relating to the junior rower including age, gender, and frequency of training, this study may provide an opportunity to compare with other studies and improve understanding of injury risk in junior rowers. Furthermore, researching injury prevalence in junior rowers provides a platform for future research to identify potential intervention strategies to reduce injury rates, and therefore enhance the longer-term continuity of rowing. Moreover, Mechelen (2012) recognised a need within sports injury surveillance systems, acknowledging reports should be able to answer, “how many, how often, how long and how serious?”

Chapter Three: Methodology

Study Design and Approach

This study primarily adopted a positivist, prospective approach as it examined mainly quantitative injury data from a cohort of junior rowers, in order to obtain factual information on injury incidence in adolescent rowers (Shepard *et al.*, 1993; Thomas, 2006). There were also some open-ended questions allowing for qualitative data collection. The primary data collection tool was an injury questionnaire, administered to rowing clubs online over a period of six months. Following procedures outlined by Murphy (2014), a mixed methods approach of quantitative and qualitative designs was adopted. This combined a numerical measurement with in-depth exploration by using a range of open and closed questions, single answer, and multiple answer questions. The selection lists and free text segments provided the opportunity to offer a case-study approach per submission, helping capture the reality of the injury more accurately and meaningfully. This provided the opportunity to measure and categorise injury rates and identify patterns in the research; whilst providing corresponding qualitative information for further insight into the context surrounding the injury. In turn, giving capacity to address the practical problem of sporting injuries in rowing.

Study Sample and Recruitment

Due to the nature of the study, a non-probable purposeful sampling technique was used to select clubs with members aged 11-18, with no requirement of expertise prior to commencement (Hasan and Parvez, 2015). Using the British Rowing (2019_b) club finder, 370 rowing clubs were contacted to determine their interest to participate in the injury reporting structure for six months. In total, 9 school boat clubs and 28 amateur clubs registered to engage in the reporting process within England, providing access to anonymised injury record data on 1664 male and female junior athletes (907 females to 757 males) aged 11-18.

Clubs were asked to report injuries from September 2019, and schools from October 2019: with an expected finish date of March 2020. Alongside emailing clubs and schools, posting on social media allowed the research to be shared on a wider scale with members of the

British Rowing community around England. Reaching out by social media for an online study was based on the earlier work of Duggan (2015), who purported that those who have social media will more likely engage with online work, due to the habitual nature and confidence in using smartphones and other web-devices. The questionnaire included the rowing club's registered name, geographical region, specification if a club or a school, and a contact email for each junior coordinator. Geographical location was identified by the post code and this informed on the socio-economic status in accordance with Street Games (2015) deprivation map explorer. Recruited clubs were from the following regions; Northern, North West, Yorkshire, West Midlands, East Midlands, Thames, Eastern, WAGS, Wessex, and South East Coast and Western. According to Street Games (2015), 57% of clubs were found to be in the 40% least deprived neighbourhoods in the country, whereas 23% were in the 50% most deprived areas and 20% were amongst 20% of the most deprived neighbourhoods in England.

Ethical Approval

The key ethical concerns for this study were the consent process, when seeking consent for the use of data from junior rowers to guarantee anonymity, and ensuring injury reports are stored confidentially and securely, in compliance with the Data Protection Act (2018). In accordance with regulations on GDPR, clubs did not report athlete names or identifying information. Moreover, boat clubs were identified collectively as their respective regions as recognised by British Rowing, to support anonymising their location. All research was acknowledged as voluntary, and the clubs were given the right to withdraw their data upon termination of the study or during the reporting period. Upon completion, clubs and schools were instructed that they could request a copy of the research and the right to further contact with any queries relating to the study. Prior to the commencement of participant recruitment, ethical approval from Durham University's Sport and Exercise Science Ethics Committee was granted.

Upon initial contact, junior section coordinators at the participating clubs were asked to complete an electronic Google Form, providing consent to the research (see Appendix A). The consent form requested the coach to fill in the club's name, a main point of contact for the research, and the total number of junior athletes at the club (by gender). In addition, in compliance with the University's ethical approval standards, clubs were emailed the following documents;

- Coaches' information sheet (Appendix B).
- Coaches' privacy note (Appendix C).
- Consent from (Appendix D)
- Parent/guardian information sheet (Appendix E)
- Parent/guardian privacy note (Appendix F).

Upon completion of all documentation required, the reporting document followed covering a six-month period with the aim of helping differentiate reported injuries that adolescent rowers (up to racing age J18), may attain through their junior rowing programme.

Injury Exposure Records

Following the primary email, the scrutiny document was forwarded to the coaches who committed to take part in the research. The exposure report form was adapted from the work of Fuller *et al.*, (2006), who conducted a consensus statement on injuries in football. Injury reports were declared by the athlete to the coach, who filled in the report form on their behalf. In some instances, reports were confirmed by a medical specialist. The Google Form entailed a series of questions that requested information based upon an athlete's injury experience, taking approximately five-minutes per report to complete. If one athlete sustained multiple injuries during the six-month reporting period, each injury would be recorded and treated in isolation. If an injury report had already been completed for an athlete and the same injury reoccurs later in the study, coaches were asked to report it as a separate form but state that it was a recurrent injury. Coaches were asked to report previous injuries attained by athletes, providing it was still problematic when the study commenced. If an athlete was still injured when the study terminated, it should be given consideration as to how long they will be out of training for in the future.

Data Analysis

Clubs who provided no data during the six months were followed up; three were subsequently removed from the research. This reduced the total study sample to 34 clubs, 1530 junior rowers (803 females and 727 males). The following variables were compared: gender, age group, height in centimetres, mass in kilograms, hours trained per week, date the injury occurred, the location of the injury, attainment of the injury (whether it were sustained in racing or training exposure), classification of injury, if the injury was reoccurring, and the severity of the injury.

Quantitative results were collated to generate means to explore the frequency data for responses and reported measures, such as age and height. Results were presented in the form of percentages and graphs for visualisation of any differences. Qualitative results in the form of open questions were copied in verbatim to prevent misinterpretation of feedback, and analysed by in-depth explanatory data, allowing to draw out patterns from concepts and insights (Arkkelin, 2014).

Chapter Four: Results

4.1 Total Number, Type and Severity of Injuries

The total sample included 1,664 male and female junior athletes from 34 boat clubs. At the end of the surveillance period, the total study sample was 34 clubs, 1530 junior rowers. A total of 60 injuries were recorded during the six-month reporting period (3.9% of the sample).

4.1.1 Location of Injuries and Injury Settings

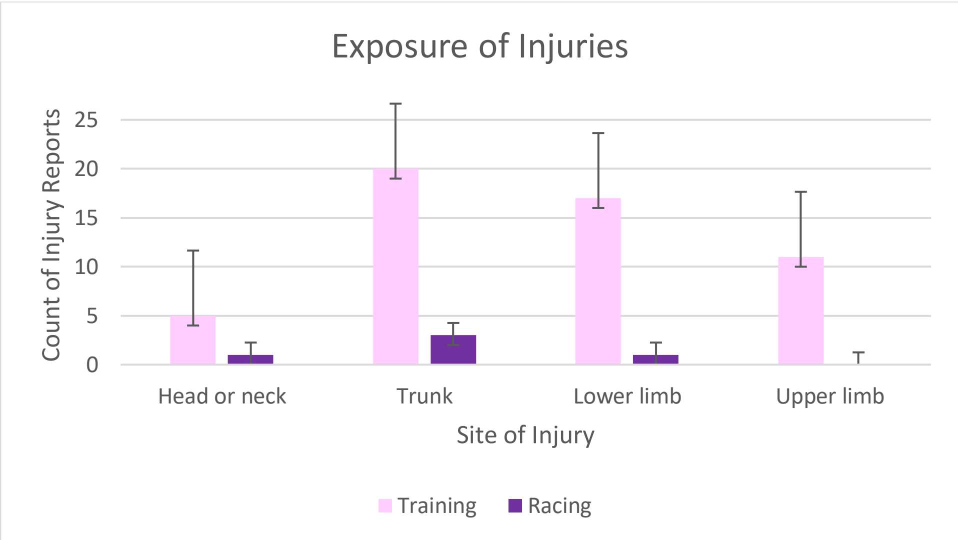

Figure 3: Training and Racing Injuries by Type/Location.

Data from **Figure 3** summarised the type/location of the injuries recorded. 12% ± 2.03% of cases occurred during racing. There were no upper limb injuries sustained during racing; most injuries were sustained during training. Trunk and lower limb injuries were most common in indoor rowing sessions, whereas upper limb injuries were most common in water sessions. The majority of injuries occurred at the trunk and included twelve reports of LBP, including one with pain travelling from the lower back into the glute, two for the middle-upper back and three with no specified region. Back pain was described as "*strains, pulls and niggles, overreaching at the catch*" and two reports of "*lifting the boat into or out of the water, onsetting the pain*". A coxes' injury report included bruising due to the spine colliding with the boat during water training. There were three rib injuries, with one suspected stress fracture. Additional text within the injury reports referred to these injuries as *"a dull niggle that progressively worsened"* or *"a sharp pain"*.

The most common lower limb injury was of the knee (n=12) (**Figure 4)**, including one report of knee pain that *"travelled through to the rowers' shins"*. Onset of knee injuries were related to; indoor rowing inducing a locking motion within the knee, sweeping, abrasion, swelling and alternative sporting injuries. Qualitative information from the coach described that the knee pain initiated as the rower experienced a growth spurt, triggering a "*burning sensation*" as the rower flexed and extended the knee joint. From an athlete's perspective within the document, knee pain commenced in land-based training which worsened when in head racing season. There were four accounts of hip pain with suspected hip impingements caused by sweep rowing and strength and conditioning training. Three ankle injuries were reported from twisting of the ankle. Lower limb injuries were one foot injury and one thigh abrasion. Upper limb injuries presented as damage to the wrist (n=4) and shoulder (n=4), followed by two reports of phalange injury, one report of forearm pain and one report of elbow swelling. Qualitative information attributed upper limb injuries to strength and conditioning-related injuries, aggravation from the feathering motion within the boat and *"possible tendonitis"*. Head and neck injuries were one of the lowest reported sites, with two reports of neck cramping, one fainting causing a "bang to the head" from lack of food prior training, and one suffered a head injury from engaging in another sport, leading to concussion and time out of rowing training. Although the injury was not sustained during rowing training, it impacted on the training there-on after and should not be neglected from injury reports.

The most reported site of injury was the trunk, including; ribs, sternum, upper back, abdomen, lower back, and pelvis, accounting for 38.33% ± 14.28% of total injuries. The second highest report was lower limb injuries accounting for 18 reports ± 7.39, covering the hips, thighs, knees, lower leg, ankles, and feet. The site with the lowest reported injuries were those who took time from training due to immune system-related illnesses (2 ± 0.82). Reports were also lower in rowers with head or neck injuries (6 ±2.45). **Figure 4** shows that those who were at the highest risk of a trunk injury trained 1-4 hours per week, followed by those who trained 5-7 hours/week. This is consistent throughout the findings from each site of injury. Upper limb injuries were reported in rowers who trained 7 hours a week, with more reports at 11-15 hour/week. Lower limb injuries were more common in rowers training 11-15 hours/week, but also present at 1-4 hours and 7-10 hours.

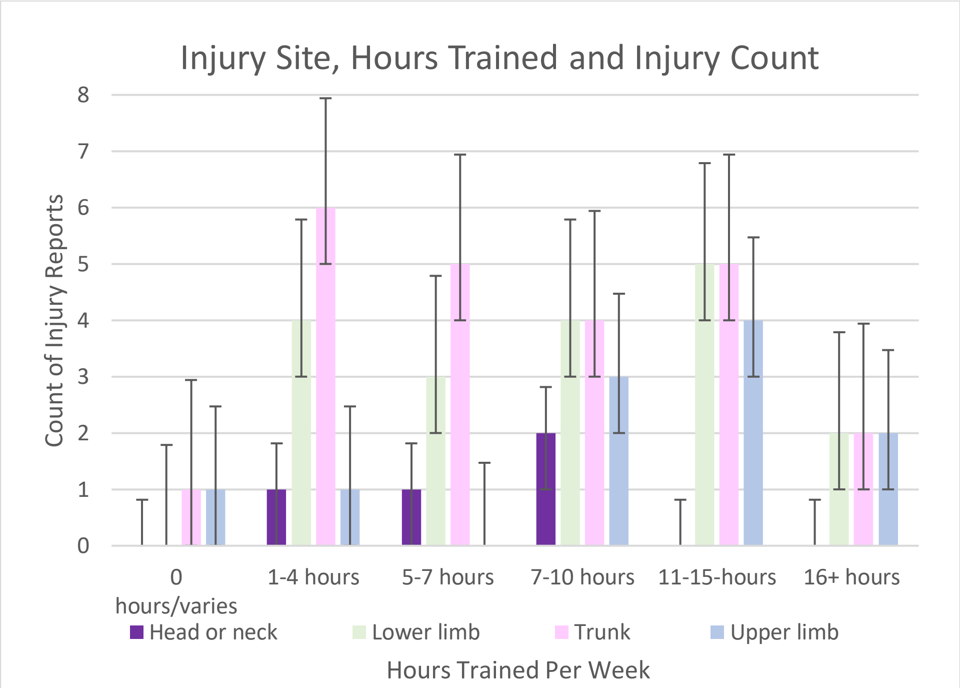

Figure 4: Junior Rower Injuries and Frequency of Training.

4.1.2 Classification of Injuries

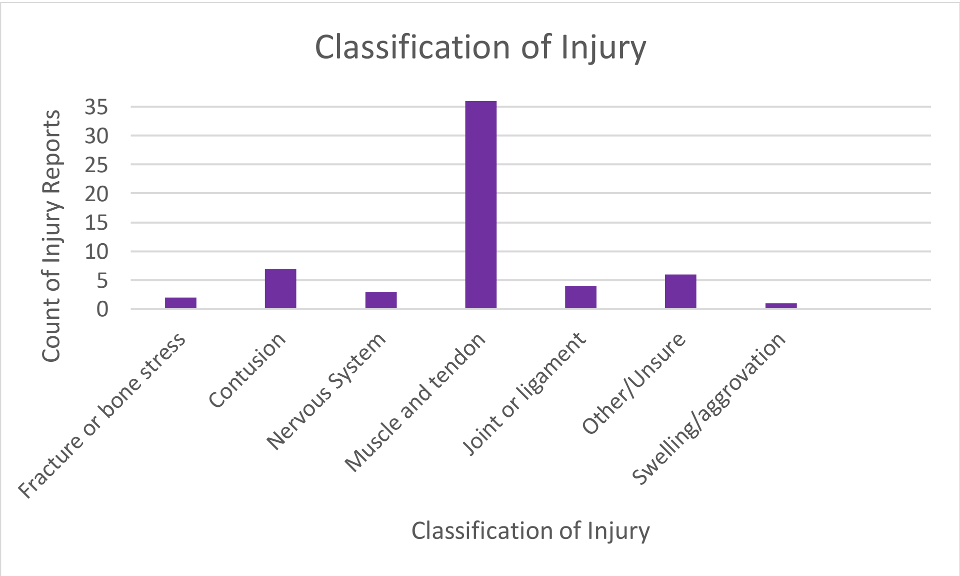

Figure 5: Classification of Injury.

60% of total injuries were muscle and tendon-related (**Figure 5)** and 10% of cases were unclassified (no category). The lowest reported classifications were related to; swelling, aggravation, fractures, or bone stress. Head and neck injuries were mainly muscular and tendon related injuries, as were trunk injuries. 50% of lower limb injuries were muscle and tendon injuries, with other classifications accounting for contusion and joint/ligament damage. Similarly, 50% of the upper limb injuries were accounted for from muscle and tendon damage, $^{1}/_{3}$ classified as contusion, and 10% classified as joint and ligament damage.

4.1.3 Severity of Injury

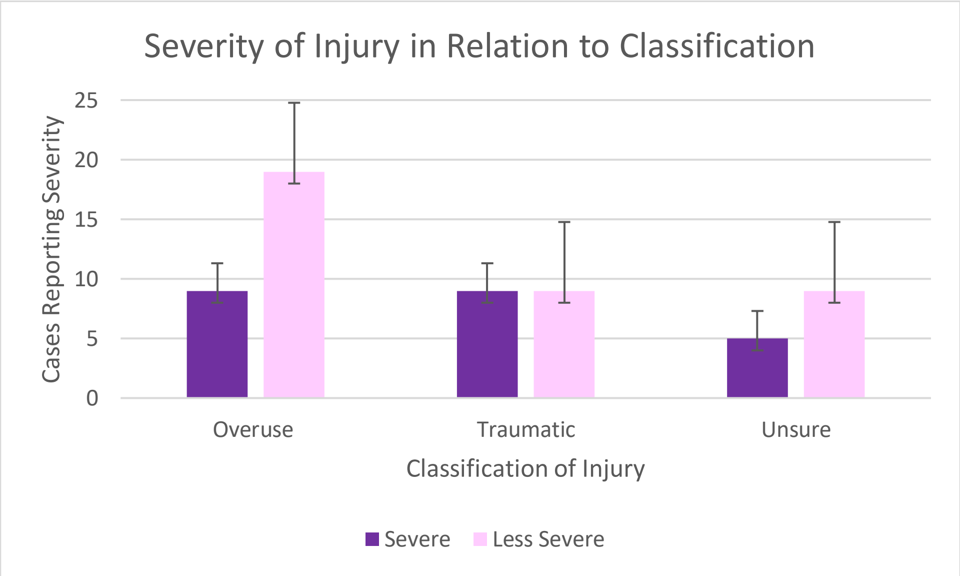

Figure 6: Severity of Injury in Comparison to the Classification.

There are research complications when defining the severity of an injury, as severity may differ as a matter of opinion between sportspeople. By using the descriptive questions within the Google Form, subjective determinations could be made based on severity of the injury. Time taken to return to sport, period of adaptive training and treatment received were all taken into consideration to determine each one's severity. Encapsulated above, 9 ± 2.31 of overuse injuries were classed as severe, in addition to 9 ± 5.78 of traumatic injuries being categorised as severe. A large proportion of overuse injuries were identified as less severe totalling up 31.67% of injuries. From the undetermined group that could not classify their injury, 64.29% of reports were rated as less severe. Using descriptive analysis, head and neck injuries were determined by their severity based upon time out of training, whereas injuries of a lower severity were overcome with periodic stretching and home treatment. Lower limb injuries were determined severe if; training was terminated, they could not reach full-catch extension without pain and being unable to complete everyday tasks. Less severe cases adopted adaptive training and injuries eased with home treatment and stretching. Trunk injuries were treated as severe where time out was over extended periods of time, or the athlete did not return and had to seek physiotherapy. Less severe instances adhered to reduced workloads, reverted from sweeping to sculling and used home pain-management techniques to treat injuries. Lastly, upper body injuries were determined as severe if months were taken out of training. Less severe instances were categorised by short periods of adaptive training, feelings of mild discomfort and altering session plans to reduce aggravation.

4.1.4 Injury Reoccurrence

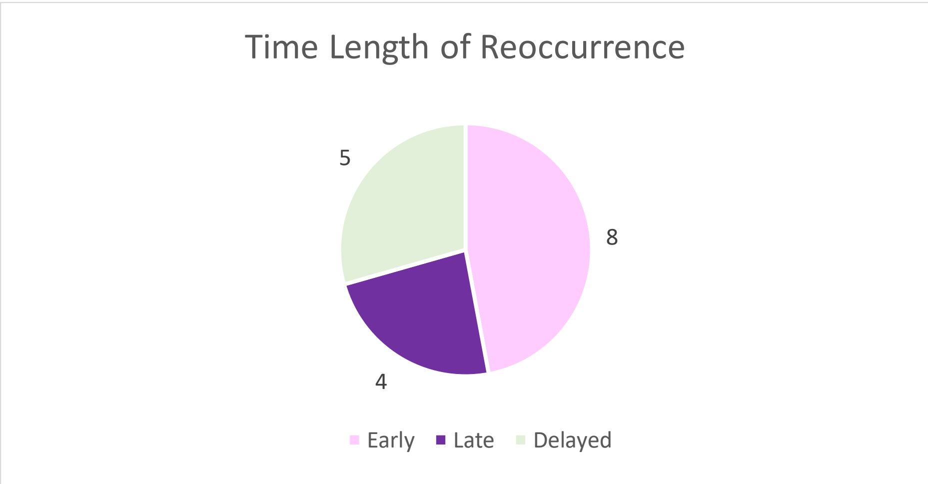

Figure 7: Time Taken for Injury to Reoccur.

Early reoccurrence within the first 2 months after returning from the injury was reported in 47% of instances, as seen in **Figure 7**. In comparison, late occurrence within 2-12 months after returning, accounted for 24% of the cohort's reoccurrence rate. Finally, a delayed occurrence, onsetting after 12 months from the initial injury, accounted for 29% of the reports.

4.2 Influence of Gender

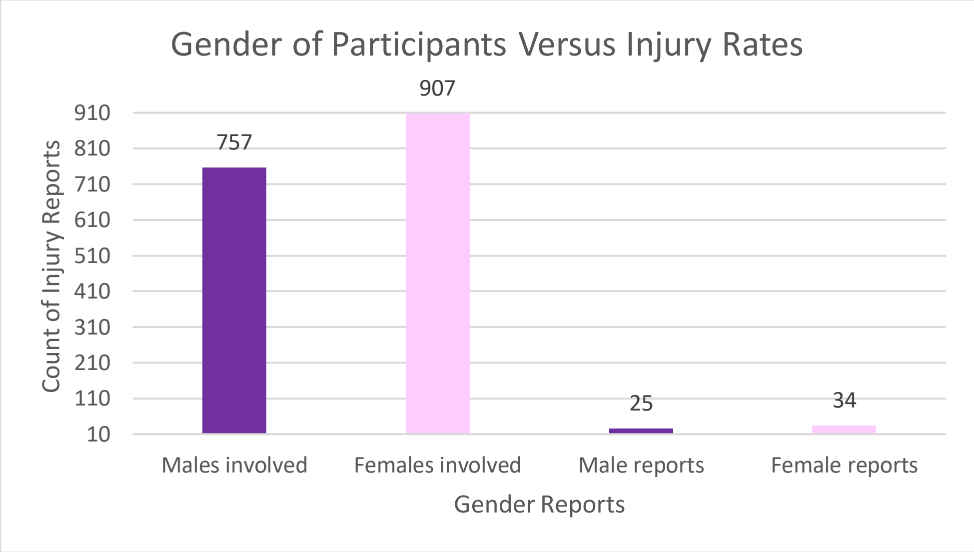

Figure 8: Gender Split of Participants Within the Study, and Injury Adherence.

Overall, more females than males sustained injuries during the six-month reporting period; 56.7% females to 41.7% males. From the 727 males who agreed to take part, 3.3% actively reported an injury; from 803 females participating, 3.8% recorded injuries (**Figure 8)**.

<u>*4.2.1 Site of Injury, Frequency of Training and Gender*</u>

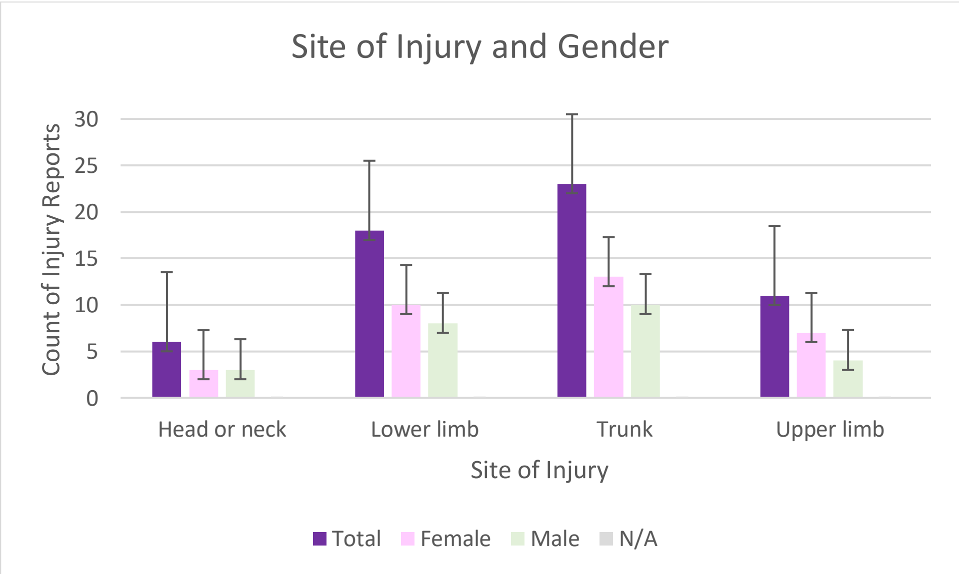

Figure 9: Site of Injury Separated by Gender.

In relation to gender, more females than males sustained injuries regardless of injury site, with the incidence more common at the trunk and lower limb for both genders **(Figure 9)**. The same number of males to females sustained head or neck injuries during the 6 months.

4.2.2 Injury Reoccurrence

Figure 10 presented data on injury, recurrence, and gender. Injury reoccurrence was 45.45% higher in males than females, putting females at a 17.24% risk of sustaining another injury. In comparison, males appeared more likely to report a reoccurring injury, with a 78.57% chance of it occurring again.

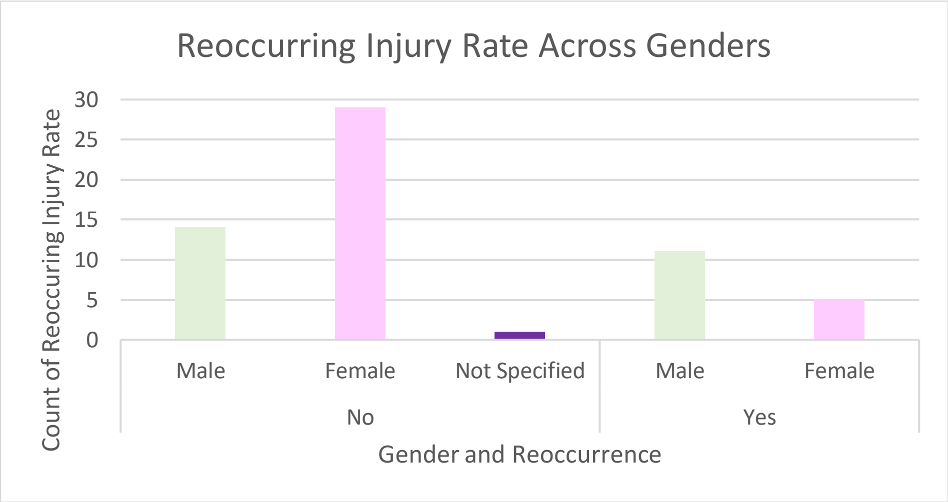

Figure 10: Reoccurrence of Injuries Across Males and Females.

4.3 Influence of Training

4.3.1 Training Frequency, Experience and Injury Rates

Those training for 7-10 hours per week reported the highest injury rates (**Figure 11),** which is equates to approximately three sessions per week. Although varying, the trendline shows a minor but gradual decrease in injury count reports as training frequency increases. Outliers include those who did not specify training occurrence, those who did not engage in any rowing over the six months, and coxes.

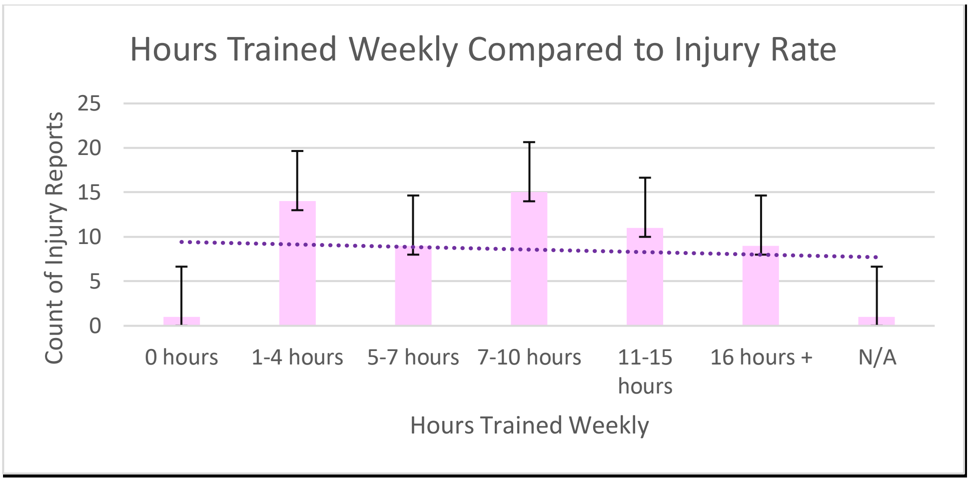

Figure 11: Hours Trained Weekly in Comparison to Injury Rates.

The trendline in **Figure 12** shows a greater downtrend than **Figure 11.** This illustrates that the more experience a rower has, the less at risk they are of attaining an injury. When comparing both graphs, rowers were at a reduced predisposition when they had more experience and commit to greater training loads. The highest injury reporting rates were in those who have been training for 1-2 years, followed by those training 3-4 years ± 9.14. There is a significant decrease in those who have >4 years' experience, with very few cases of injury reports.

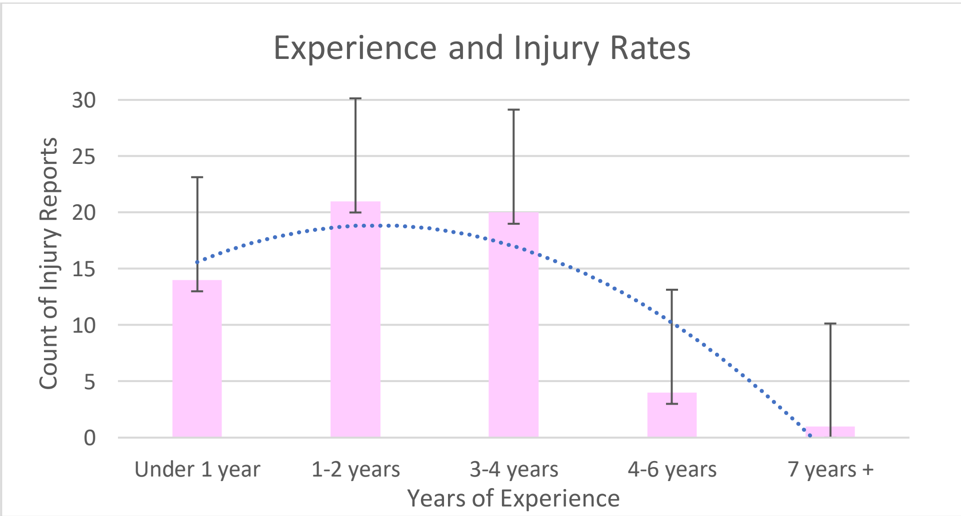

Figure 12: Years of Experience in Comparison to Injury Rates.

4.4 Influence of Age

Age range varied between 12- and 18-years within the injury reports as shown in **Figure 12.** The graph illustrates that the highest reported age for injuries was within J16 rowers with 14 reports, followed by J15 with 12 and J17 rowers with 10 counts. Gender split shows that the age group with the highest injury report for boys was J16, with 71.5% of injuries. The highest female injury reports were in J15 rowers, with 66.67% of injuries from girls.

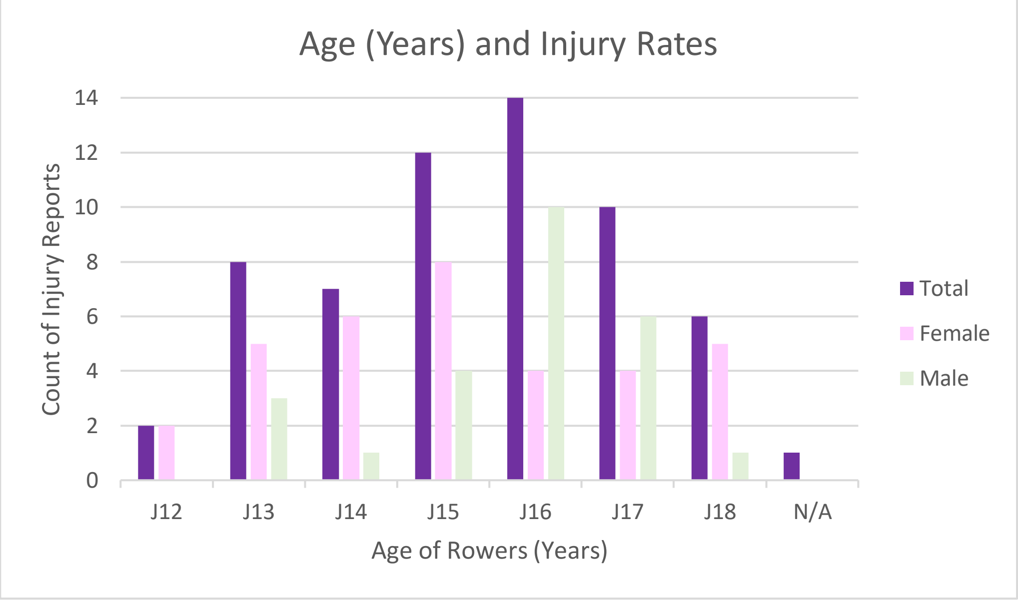

Figure 13: Age Range in Comparison to Injury Reports, Split by Gender.

In comparison, **Figure 13** shows that the age group with the lowest report of injuries were within J12 rowers making up 3.33% of the surveillance data, and J18 rowers attributing to 10% of reports. Males were least susceptible to injuries ages 14 and 18 with the lowest number of reports 7 and 6 respectively, and females least at risk aged 12 with 2 reports, with the next lowest age doubling in injury rates in 16 and 17-year-old rowers.

4.4.1 Injury Recurrence by Age

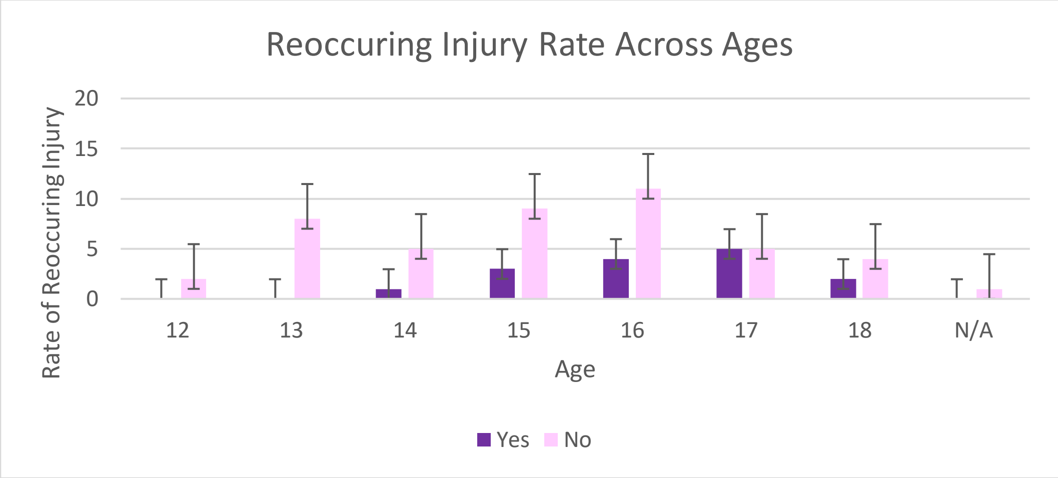

Figure 14: Reoccurrence of Injuries Across Age Groups.

Figure 14 compared rate of reoccurrence within each age. The age range at the highest risk of reoccurrence was J17s, with 50% of the age range injury-free after one episode, and the other half sustaining another injury after a previous one. J16s were the next age range most likely to have a reoccurring injury with a 36.36% chance of injury reoccurrence. There was an insignificant increase in rate of reoccurrence as age increases, dropping again from J18.

4.4.2 Growth and Injury Reports

The lowest recorded height amongst the injury reports was 140cm, and the highest at 184cm; a 44cm difference across the reports. **Figure 15** shows that those 165-169cm tall reported the most injuries (n=12), followed by those 170-174cm (n=10). Rowers 140-149cm tall reported the least number of injuries (n=3). The 'N/A' group were reports from rowers who did not record a height. **Figure 15** also analysed difference in height relative to gender split. Females who were 160-169cm, over two height brackets, reported the most cases of injury with 14 reports ± 2.27, whereas lowest injury reports were at either extremity of the scale; 140-144cm and 180-184cm. In males, the highest reported number of injuries were rowers 170-174cm and 180-184cm tall, with 10 and 7 reports respectively (± 2.22). The lowest number of reports covered 145-164cm over four height brackets, with only one injury report in each.

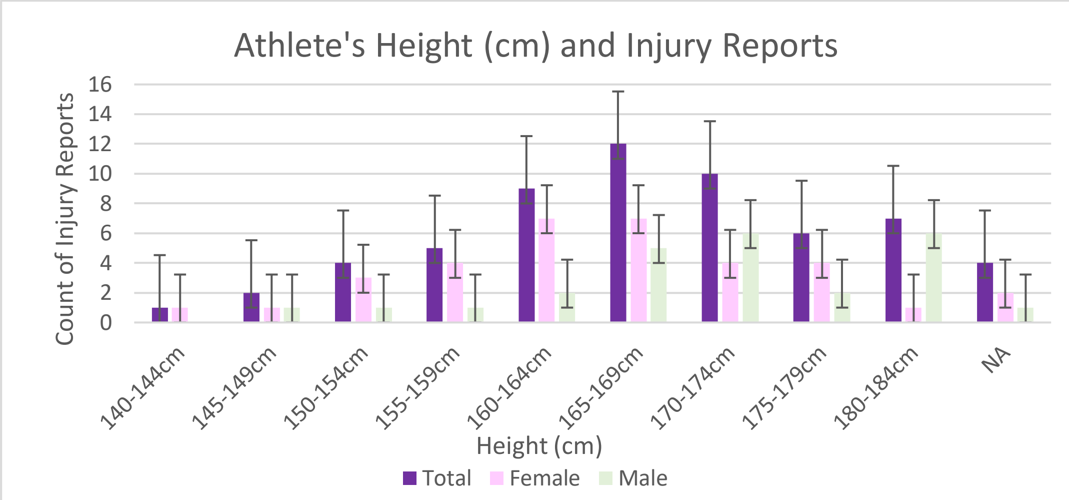

Figure 15: Height and Injury, Split by Gender.

4.5 Regional Differences

Clubs (n=34) were categorised by their respective regions, as opposed to individual club names. Seven Northern clubs agreed to take part in the research, followed by five from the North West and five from Thames's boat clubs. Yorkshire, East Midlands, and Wessex/South East Coast all had two clubs enter from each region, with one entry from the West Midlands, one for Eastern and one club from the Western area. Analysing the reported cases within each region, the most cases originated from Northern clubs, followed by Yorkshire and then East Midlands **(Figure 16)**.

1. Northern Clubs – 3.71 cases per club
2. Yorkshire - 3 cases per club
3. East Midlands - 2.5 cases per club
4. Thames – 1.6 cases per club
5. North West - 1.4 cases per club
6. Eastern - 1 case per club
7. Western - 1 case per club
8. Wessex/South East - 0.66 cases per club

All ten regions reported at least one junior injury during the six months of data collection. The four clubs with the highest reporting injury rates, with four to six injuries per club, were in the top 40% of the most deprived neighbourhoods in England. An additional six clubs located within the top 30% of the most deprived areas submitted ~three injury reports each. The remaining 60% of clubs only submitted one to two reports each and were from the top 40% of the least deprived postcodes. Just under 30% of clubs who agreed to take part did not report any injuries. Six were within the top 40% of the least deprived neighbourhoods, two from the top 40% of the most deprived, and one from the top 30% most deprived areas.

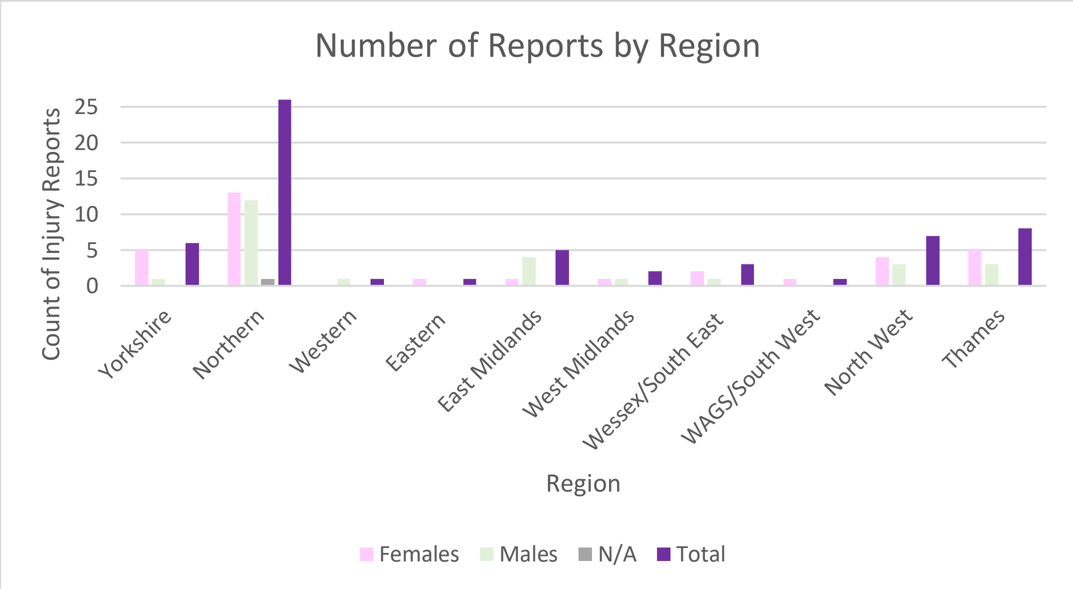

Figure 16: Participating Rowing Clubs by Region.

Figure 16 also highlights gender split respective of each region. On the whole, female injury rates were slightly higher than males except within the West and East Midlands, where more males reporting injuries than females. Yorkshire reported the highest gender difference, demonstrating a 5:1 ratio that females would attain a rowing injury in comparison to male counterparts.

<u>4.5.1 Regional Area, Identifying Deprivation Rating and Gender Split</u>

Club deprivation rating was compared to gender and injury rate (**Figure 17)**, attributing 45% of injuries to those from low SES areas. 30% of injuries were from rowers in the top 50% of the most deprived neighbourhoods, and the remaining 25% from the top 40% of the least deprived areas. This suggests those from a higher SES area are at the lowest risk of injury, whereas those from lower income backgrounds were at a higher risk. Females from lower SES areas were at a 31.2% increased risk of sustaining an injury compared to males, whereas males from higher SES backgrounds were at an increased risk by 20%.

Deprivation Rating	Gender	Count
Top 30% most deprived areas	Males	11
	Females	16
Top 50% most deprived areas	Males	10
	Females	8

Figure 17: Club Deprivation Rating Relative to Gender Split and Injury Count.

4.6 Reports of Immune System Illnesses

Within the research findings, immune system illnesses became prevalent towards the end of the six-month reporting period. Although illnesses are not necessarily injuries presented through rowing, the impact of an illness can have impending consequences on a rower's return to training, for instance recovery time and potential adaptive training upon return to sport. Those with immune system injuries were diagnosed with symptoms of Covid-19 and therefore had to take time out of training and self-isolate. There was also one reported incidence of pneumonia as a result of a capsize. Fortunately, immune system illnesses were the lowest reported classification of injury. As the cases of immune system illnesses were linked to pneumonia and coronavirus, they were both treated as severe by nature.

Chapter 5: Discussion

The purpose of this study was to assess injury incidence and associated factors in adolescent rowers over a six-month reporting period. This discussion underpins physiological reasoning that offers suggestion as to why some juniors may be more susceptible to injuries than others, and what places rowers at a greater predisposition to injuries.

In summary, the first key finding was that injuries were more common in junior rowers at the age of 16. Injuries at this age, comprised 23.33% of all injuries reported, with no significant sex differences in incidence rates. There were no notable differences between hours engaging in weekly levels of exercise training, yet different compared to experience levels, where injury rates depleted relative to experience. Second, the most reported site of injury was the trunk accounting for 38.33% ± 14.28% of total injuries. Third, a significant proportion of injuries were reported to have been sustained during training rather than in the competitive environment. Injuries were more likely to be muscular and tendon-related as a result of overuse as opposed to traumatic episodes. Fourth, recurrent injuries were more common in males than in females, with an early reappearance within two months. Finally, the four most actively reporting regions during the research were correlated with the highest injury rates, whilst being located within the top 40% of the most deprived neighbourhoods in England. These findings have relevance to athlete injury prevention strategies and junior rower development pathways.

5.1 Explaining Injury Incidence in Junior Rowers

Sports injury classifications are based on an injury's location, type, side of the body, and reoccurrence (Fuller *et al.,* 2006). Providing a classification system when analysing sports injury reports helps deliver an in-depth analysis for each injury sustained, to support with future diagnosis and prevention strategies.

5.1.1 Site of Injury

The most common anatomical site of injury was the trunk region, comprising 29 out of 60 reports. This is supported by the findings of Finlay *et al.,* (2020), who analysed site of injuries within more discrete locations, showing the lower back as the most frequent site of injury, followed by the knee and then the shoulder. The anatomical site of injury has been explored by several studies, classifying the lower back, shoulders, knees, and ribs as the key sites of injury in elite-level rowers (Foss *et al.,* 2012; Arend *et al.,* 2016; Harris *et al.,* 2020). In the current study, although shoulder injuries were still recorded, they were not as prominent in the findings of the surveillance document within junior reports, affecting only 6.67% of juniors. Research into shoulder pain has been associated with sweep rowing, suggesting why shoulder injuries are few amongst junior injury research, particularly when looking at younger age brackets, as juniors cannot engage in sweeping until at least the age of 15 (Henley Rowing Club, 2018). Even then, some clubs do not pursue sweep rowing in juniors until full maturation, to avoid risk of muscular imbalance and injury. Nevertheless, sweep rowing in existing studies only account for 5-10% of reports, with 90% of injuries experienced by scullers (Bernardes *et al.,* 2015). Conflicting research by Smoljanovic *et al.,* (2009) reported the onset of LBP in rowers who altered sides during sweep training, as opposed to upper-limb injuries.

Training load associated with site of injury helps identify who is at risk, which anatomical sites pose the highest risk, and how this differs depending on time committed to training weekly. This research demonstrated that trunk injuries arise more often in athletes who train the least, whereas upper limb injuries correspond with athletes who train the most. This is contradictory to the research of Core (2016), who reported that back injuries are commonly associated with intensive training programmes and overtraining. The contradictory findings between Core (2016) and the current study may be an indication that rowing as a sport introduces juniors at a later age, meaning they have had no prior exposure to rowing training before, and are therefore more likely to make common technical and training-related mistakes. Like many sports, prolonged periods of practicing incorrect technique places athletes at an increased risk of injury, due to incorrect load management, improper body placement and potential repetitive strain (Elliott, 1998; Gabbett and Ryan, 2009). As a result, injuries often sustained by novice rowers include; back and knee injuries from overreaching through the catch; injuries to the lumbar spine from incorrectly driving off the foot plate; and upper limb injuries through gripping the handles too tight and feathering incorrectly (Bull and McGregor, 2000; Rumball *et al.,* 2005). This suggests that further research needs to be undertaken to fully elucidate associations between training load and injury site, as McDonnell *et al.,* (2011) proposed that volume of training may be an ineffective factor when analysing injuries, whereas Hosea and Hannafin (2012) identified a direct link between injury incidence and training volume. This should be investigated further, particularly when working with junior athletes to resolve the discrepancies in research.

Relative to training time, those engaging in three sessions per week were at the highest risk of reporting an injury. When training adolescents, although they may specialise in one sport, they still engage in multiple other sports as a result of compulsory physical education and extra-curricular sport (Committee on Physical Activity and Physical Education in the School Environment; Food and Nutrition Board; Institute of Medicine, 2013; LaPrade *et al.*, 2016;). Therefore, although an athlete is only taking part in four hours of rowing a week, they can still be at risk of overtraining if engaging in multiple other sports and training programmes. Lombard (2018) therefore proposes that an athlete-centred approach would be beneficial for developing robust, well-rounded athletes across a variety of sports, as opposed to a specialist in only one until later adolescence or the onset of adulthood.

<u>Trunk Injuries</u>

The findings of the current study highlighted trunk injuries as the most common site of injury in junior rowers, particularly emphasising LBP caused by muscular strains, niggles, pulls, overreaching at the catch and incorrect form when lifting equipment. Thornton *et al.*, (2016) signified LBP within training was relevant to the volume of training engaged in. Similar findings from NG *et al.*, (2014) recorded a strong association between LBP and indoor rowing sessions which exceeded thirty minutes; averaging around 6000 meters ± split time. Within many endurance-based sessions, distances covered often exceed 10,000 meters within one training session. These findings are reinforced by Wilson (2010), who established a strong relationship between ergometer training and injury risk within rowers (r=0.68). Everything considered, Karlson (2000) accentuated technical errors and training procedures as the empirical pressure point for the majority of back-related injuries sustained by rowers, as opposed to within the competition environment. With relevance to trunk-related injuries, the study identified one coxing injury. The cox's responsibility is to steer the boat and manage the crew, whilst sat at either the stern or the bow of the boat (Cambridge University Boat Club, 1938). Although overlooked in rowing injury research, coxes are also susceptible to injuries, in particular to the middle and lower extremities of the spine and should be considered as a risk of the sport. The surveillance document reported bruising to the athlete's back after colliding with the boat during water-based training. Skin abrasions in coxing are not exhibited within rowing research yet are a common occurrence. Therefore, the foundations of research on coxing injuries is required to consider how common these injuries are, the short- and long-term impacts injuries can have on coxes, and suitable preventative measures to mitigate the injuries.

Lower Limb Injuries

The most commonly reported lower limb injury within this study was knee-related pain. Exposure of lower limb injuries during the study included; onset during indoor training, a locking sensation within the knee, sweeping, abrasions and swelling. Common knee-related complaints addressed by Thornton *et al.,* (2016) are said to be triggered by inflammatory responses as a direct result of overuse irritation, causing patellofemoral pain syndrome, tendinopathy, and iliotibial band friction syndrome. Considering the physiology of the patellofemoral joint and its role within the rowing stroke, the knee is extensively loaded during the drive phase of the stroke (Hosea and Hannafin, 2012), and when combined with abnormal patella tracking, can aggravate the cartilage around the knee joint (Karlson, 2000). As a result, a small percentage of knee related injuries were identified within racing, and instead commonly acknowledged within training exposures as a result of overtraining and overuse injuries. Once a knee injury has been sustained, it is not commonly eased with other forms of non-rowing specific aerobic exercise, as it can contribute to further impending knee injuries and training disruptions, thus prolonging the injury recovery period (Smoljanovic *et al.,* 2015). Analysing the explanations as to why patellofemoral complaints occurred within training exposure, Waryasz and McDermott (2008) identified weaknesses and imbalances within surrounding muscle groups including the gastrocnemius, iliotibial band, quadriceps, hamstrings, and hip instabilities contributing to knee-related pain. A muscular imbalance whilst exhibiting flexion and extension of the knee can aggregate the joint. Therefore, strengthening these muscles would impose a reduced risk of patellofemoral complaints during the rowing stroke. This further explains how underdeveloped rowers as a result of maturation who engage in sweep rowing, may exhibit knee pain due to muscular imbalances and irregular tracking motions (Kabaciński *et al.,* 2020).

Upper Limb Injuries

Upper limb injuries presented themselves in the form of damage to the wrist, forearm, and shoulder; situated as the third most reported site of rowing injuries, within both the results of this study and Hosea and Hannafin's (2012). Wrist and forearm injuries are embodied within existing injury research analysing the feathering motion of the blade, and the fatigue that comes with prolonged squaring and feathering (Thornton *et al.,* 2016), therefore attributing upper limb injuries to training exposures as opposed to racing. Undeterred training habits such as exhibiting the incorrect grip can aggravate the wrist and forearm

(Rumball *et al.*, 2005), thus causing inflammation to the tendons and muscular associations surrounding the wrist joint, including irritation to the ulna and median nerves (Colak *et al.*, 2018). Alongside technical errors, inappropriate boat set up such as improper handle sizes on blades for juniors can result in gripping abnormalities, therefore causing the irritation to the wrist area (Rumball *et al.*, 2005). Training-related exposure to wrist injuries is supported by risk management strategies to reduce inflammation. Thornton *et al.*, (2016) proposed reducing the grip to the ergometer handle during indoor training and removing the feathering motion from water-based rowing, can reduce the severity of a forearm and wrist injury, suitable for those requiring periods of adaptive training.

Upper limb injuries also recorded shoulder injuries, accounting for 6.67% of total injuries within the surveillance report. These injuries were attributed to water-based rowing; more specifically overreaching during sculling and the rotation from sweep rowing. Overreaching at the catch destabilises the shoulder position resting within the girdle and irritating the joint, weakening the surrounding muscles of the rotator cuff (Richardson and Jull, 1995; Page *et al.*, 2012). Sweep rowers commonly experience muscular instabilities within their outside arm, due to repetitive loading from the altered physiological positioning of the catch (Abbot and Hannafin, 2001). Within both sculling and sweeping, a common theme of shoulder pain is a result of improper technique commonly practiced by novice rowers, by leaning through the stroke rather than rotating into the catch position (Arumugam *et al.*, 2020).

Hip Injuries

Although the lower limbs accounted for 30% of total injuries, only four hip injuries were reported during the six-month exposure document, as a result of sweep rowing and training exposure; fearing hip impingements in all cases. Due to the nature of the injury, those diagnosed with femoral acetabular impingement syndrome do not always return to sport, as hip impingements are a critical injury to rowers and often reoccur if not recovered properly (Mottram *et al.*, 2019). This is echoed by Boykin *et al.*, (2013), who reported that only 56% of athletes with hip injuries return to the sport post-treatment. Alternatively, hip and groin pain can be attributed to labral tears (Lohan *et al.*, 2009), and without seeking medical attention can be incorrectly diagnosed. Hip injuries are often overuse, as the femoral head and acetabulum experience repeated exposure during prolonged periods of training, resulting in microtrauma to cartilage surrounding the hip joint (McCarthy *et al.*, 2001; Boykin *et al.,* 2013). Smoljanovic *et al.,* (2009) highlighted that hip impingements within rowers is predominantly focused in elite international-level athletes as opposed to grassroot club rowers, therefore cannot be generalised to the whole junior rowing population.

Rib Injuries

Rib injuries are often diagnosed as RSF, and although are relatively low in sportspeople, occur within 6-12% of rowers (Warden *et al.,* 2002) in the posterolateral segment of the ribs (Holden and Jackson, 1985). This is a result of the exposed area of the trunk at the finish position, due to maximal compression of the rib cage, placing the rower at greater risk of RSF (Wajswelner *et al.,* 2000). Injury to the ribs within inexperienced rowers is linked to incorrect boat set-up, where the handle and gate height has not been adjusted accordingly (Green and Wilson, 2000), therefore placing the ribs in a vulnerable position when the blade is extracted at the back of the stroke, which can cause a traumatic singular-event injury. Moreover, the effects of compression on the rib cage for sustained periods of time, can also instigate muscular pain within the trunk region (Warden *et al.,* 2002). Alternative reasoning for rib pain is again linked to training exposure due to programme volume and fatigue (Thornton *et al.,* 2017). Similar to hip injuries, RSF are predominantly experienced by elite rowers, in comparison to non-elite counterparts (McDonnell *et al.,* 2011). This suggests why only 5% of the injury reports within this study were a result of rib pain, yet RSF are commonly diagnosed clinically, and without medical attention can only be assumed resulting in potential reporting inaccuracy (McNally *et al.,* 2005).

Head and Neck Injuries

Head and neck-related incidents were one of the lowest reported sites within this study, yet imposed the highest risks if sustained. Current research explicitly associated with head injuries in rowing is absent, and instead looks to provide general sports-related healthcare advice for appropriate training climates; avoiding traumatic singular events that may result in injury. These occurrences were documented as a result of cramping, suffering a "bang to the head" from fainting, and dietary-related concerns from insufficient caloric intake prior to training and exercise-induced dehydration. Unlike the other sites of injury, head and neck traumas were sustained in both training and competition environments, with neither exposure posing more threat than the other. Exercise induced dehydration can negatively physiologically affect an athlete's training and performance, as a 2% decrease in bodyweight from sweat loss, coupled with inadequate pre-exercise hydration can impact blood volume; encouraging muscular cramps, dizziness, and fatigue (Maughan and Leiper, 1994; Miller and Layzer, 2005; Shirreffs, 2009). In turn, a dizzy-spell or episode of fainting can incur a head or neck injury. This is supported by the work of Ray and Fowler (2004), who highlighted reduced risk of injuries and fatigue by staying sufficiently hydrated whilst maintaining a sound nutrition plan. That being said, consuming an appropriate and adequate portion of food prior to training can reduce the sensations of dizziness, light-headedness, and risk of fainting; whilst helping avoid fatigue, injury, and burnout (Eiring *et al.*, 2017). Head and neck injuries that can occur as a result of fainting or dizziness include abrasions, concussion and in worst-case-scenario, death (Anderson *et al.*, 2006).

Immune System/Illness

Although immune system-related illnesses are not a form of injury, they still result in time out of training, requiring a recovery period and can impair athletic performance upon return depending on the severity of the illness; with a potential requirement for adaptive, tapered training upon return. It is also important to consider the effects that athlete burnout and overtraining can have on the immune system, causing a cyclic effect on returning to sport if the burnout and illness pattern is continued. Gleeson (2007) reported that prolonged periods of strenuous exercise if not managed accordingly, can negatively impact on an individual's immune system functioning. Gleeson also noted that athletes are at the highest risk of supressing their immune system when training sessions exceed 90 minutes, at a moderately-high intensity, and are performed with inadequate food intake. Later work by Keaney *et al.*, (2018) added sleep deprivation, psychological stress, competition pressures and travelling as contributing factors to reducing an athlete's immune system. In turn, the presence of these factors places athletes at a higher susceptibility of contracting viruses and infections, particularly when leading up to competitions.

Specific to the timing that this research was close to completion, the country was exposed to a global pandemic, which resulted in a nation-wide lockdown in March 2020. Covid-19 presented itself around January as a severe acute respiratory syndrome (Parnell *et al.*, 2020), which is highly contagious and can be acquiring through physical interaction, close proximity and respiratory droplets (Centres for Disease Control and Prevention, 2020). Due to the nature of the illness and how it affects the respiratory system, performance athletes returning to sport after testing positive and self-isolating for a period of time were advised to undergo a medical evaluation, for coaches to understand their level of fitness and risks of pertaining health conditions (Dores and Cardim, 2020). Coronavirus symptoms can be prolonged post-infection period otherwise known as Long-Covid and can have longer lasting effects on both health and sport. Despite the imposed lockdown not effecting the count of results for this study, a small proportion of athletes within the cohort did possess symptoms and had to isolate in February/March. Consequentially, if the study had of exceeded six-months of reporting, figures may have drastically changed for those returning to activity post-Covid19, including likelihood of contracting the virus, adaptive training when recovering, and the risk of injury when returning to participation after a sustained period of time-out (Waddington, 2020).

5.1.2 Classification of Injuries

In total, over half of the entries during the six-month period were attributed to muscular and tendon-related injuries, with a large proportion of reports accredited to LBP as seen in **Figure 5**. Research by Thornton *et al.,* (2017) affirmed the high reporting of musculature injuries, in particular to the trunk, suggests rowers were at a greater predisposition of hyperflexion, twisted forces and compressed loads. In turn, impairing the contractibility of muscular fibres causing inflammations to both tendons and ligaments, and deteriorating the muscular structure. In comparison, 50% of lower limb injuries were attributed to muscle and tendon injuries, with the remaining 50% spread across contusions and joint or ligament damage. The lack of weight baring activity in rowing reduces susceptibility of meniscal and ligamentous damage, but instead triggers inflammatory responses to tendons and cartilage, initiating patellar pain (Fairclough *et al.,* 2006). Similarly, upper limb injuries sustained the same response, where half were associated with muscle and tendon damage, then contusion followed by joint and ligament damage. Common classifications are a result of tendonitis, tightness, and hypotrophy of individual muscles (Rumball *et al.,* 2005). The least number of reports were classified as fractures and contusions. Finally, in total, 10% of cases were left as unclassified as the coach did not know which classification the injury fit into. The lack of professional physiotherapists within grassroot clubs highlights the risk of injuries becoming misdiagnosed or inappropriately treated, if medical attention is not sought outside of the club setting (Bolling *et al.,* 2020).

5.1.3 Exposure Reporting

A further key finding was that most injuries were sustained in the training environment as opposed to competition. In addition, the most common exposure that trunk and lower limb injuries presented themselves in was indoor rowing, whereas water sessions were commonly associated with upper limb injuries. This is supported by the work of Wilson *et al.,* (2010), who reported ergometer training as the main source of injury in rowers (r=0.68, p=0.01). Similarly, Newlands *et al.,* (2015) recorded a high correlation between the training environment and the onset of back pain, instigating training to be the main exposure to rowing injuries. This is supported by Bernardes *et al.,* (2015), who found that non-contact, low-risk sports such as rowing reported 76% of injury occurrences to be from training as opposed to competition; indoor training presented the most injuries, followed by water-based training. The remaining 24% of reports in Bernardes' study testified injuries from within the competition environment, with 83% of injuries occurring in water-based competitions, compared to indoor rowing races. The alternate findings of Bahr *et al.,* (2004) found that training and competition injuries come hand-in-hand as training load increases to prepare for events. Therefore, injuries sustained within the competitive environment could potentially be caused by the accumulation of training load and technical errors, which have presented themselves within racing exposure as opposed to have manifested there (Nielsen *et al.,* 2012; Gomez and Rao, 2020), or accidental traumatic injuries induced by equipment use (Baugh and Kerr, 2016).

5.1.4 Traumatic and Overuse Injuries

Injuries within this study were classified as traumatic or overuse injuries, following the earlier methodology of Fuller *et al's.,* (2006) surveillance document. Current research on overuse injuries is plentiful (Yang *et al.,* 2012), as the early research by Karlson in 2000 attributed the vast majority of injuries to be a result of overusing the muscle. Correspondingly, research by Smoljanovic *et al.,* (2009) reported a sizable 73.8% of injuries to be of an overuse nature, and the remaining 26.2% relating to a single traumatic event. Contradicting this, research by Clay *et al.,* (2016) found more variable rates, attributing only 48% of reports to overuse injuries. Clay's work mirrored the findings of this study, where 46.67% of injuries were from overuse practice. When breaking down the injury by site, double the amount of overuse injuries in the lower limb extremities were reported, similar to the findings of trunk-related injuries. This is comparable to the results of Verrall and Darcey's study (2014), who found that the majority of overuse injuries were located in the lumbar spine and the trunk, causing significant time loss from training. Furthermore, Boykin *et al.*, (2013) identified the hips to be at risk of overuse injuries, due to the repetitive motion practiced through the hip swing, resulting in labral tears and impingements. Overuse injuries are widespread in sports like rowing, which comprise of continuous repetitions of the same movement (Bahr and Reeser, 2003). In addition, rowing poses more of a threat due to the variations between technique and training volume (Hosea and Hannafin, 2012). Many overuse injuries go unreported, as symptoms start off as minor niggles, but progressively worsen over time (Shuer and Dietrich, 1997).

Although less frequent, traumatic incidents still occur in rowing (León-Guereño and Penichet-Tomás, 2019). This study demonstrated that 31.67% of injuries from this study were caused from a single traumatic event. This is fractionally higher than the findings of Finlay *et al.*, (2020), where traumatic injuries occurred in 22% of cases, and Smoljanovic *et al's.*, (2009) findings of 26.2%. The main difference between the studies is that grassroot-level juniors were the cohort of this study, suggesting why more trivial injuries may have occurred. The work of Baugh and Kerr (2016) found boys to be at a higher risk of traumatic injuries as a direct result of accidental contact, colliding with another athlete, boat, or rigger. Baugh continues to resonate with the inexperienced athlete, and the traumatic injuries sustained through boat handling, similar to the findings of this study. Traumatic injuries as a result of inexperience is echoed in the work of Smoljanovic *et al.*, (2018), who reported LBP as a result of colliding with another crew from poorly-judged steering. Traumatic events include capsizing, resulting in cold water immersion and collision-related incidents with the boat (Gomez and Rao, 2020). Contrary to lower limb and trunk injuries, upper limb injuries reported more traumatic injuries than overuse. Similar to the classifications of injuries, the coach filling in the injury response form failed to report whether it be traumatic or overuse in 21.66% of reports. It is important to reiterate the requirement of seeking medical attention when acquiring a sports injury, in order to correctly diagnose and provide sound forms of treatment relevant to the injury.

5.1.5 Experience and Injuries

The results of this study suggest a link between rowing injuries and years of experience, with more injuries in rowers who had been training between one to two years, followed by those training three to four years ± 9.14. Arguably, specialising in one sport is detrimental for young athletes due to the risk of overuse injuries. However, researching the effects of experience on injuries has demonstrated a negative correlation between years of experience and reports of injuries (Rosen *et al.,* 2018). Research by Weerts *et al.,* (2019) supported this notion, highlighting the importance experience can have on technical capabilities, as years of experience correlated with increased lumbar range of motion ($P < 0.01$). In turn, the higher the skill level exhibited by an athlete, the less chance there was of an injury (Goulet *et al.,* 2010). Novices are at a greater risk of injury from lack of experience and increased chance of exhibiting mistakes. This supports the earlier work of Smoljanovic *et al.,* (2009) who identified novice rowers to be at greater risk of traumatic injuries, whereas experienced rowers pose more threat to overuse. Furthermore, Fordham *et al.,* (2004) proposed that experienced athletes train more frequently with fewer rest days, providing reasoning as to why this cohort may be at a greater risk of overuse injuries. Whereas Gaulrapp *et al.,* (2000) blamed poor skill acquisition and trivial errors such as speed, balance, and poor judgement on novices, resulting in acute traumas.

It is important whilst researching the impact of experience on injury rates, that it is not confused with age or maturation, as age does not necessarily reflect level of expertise (Tayara, 2019). Although injury rates were highest in juniors aged 16, that does not necessarily represent the number of years they have been participating in rowing. Older junior athletes are also at a greater predisposition of accumulating the most experience, based on having a longer amounted time to participate in rowing from the consented age of 13. The results of this study determined that there was a significant decrease in injury reports when the rowers had over four years of experience. As an athlete experiences more injuries within their sport, whether they be minor niggles or more severe cases, the way they interpret the injury will differ on an individual basis (Osborn *et al.,* 2009).

Within every sport, there are culture considerations when working with athletes that provide reasoning as to why injuries go unreported or underplayed. Within the current research findings, common themes of 'slide bite' and 'blisters' presented themselves within novice athletes yet were not reported in their experienced counterparts. These skin abrasions within rowing are known to just be 'part of the sport', and over time either reduce from toughened skin, or become insignificant to other impending injuries (American Academy of Paediatrics, 2012). However, for a novice rower, these skin abrasions are not usual and are a common complaint during training. Skin abrasions are often under-reported due to their insignificance compared to more severe injuries, yet they still have the capacity to alter training or performance due to discomfort or fear of reoccurrence, therefore should still be reported within injury research and athlete reports (Twomey *et al.,* 2014).

5.2 Influence of Age and Gender on Injury Incidence

Age and gender were two of the main physiognomies identified by Caine *et al.,* (2006) when determining higher-risk groups for sports injuries. For example, children are more vulnerable to injuries as a result of imbalances in muscular strength, flexibility fluctuations and periods of excessive strain on the joints (Maffulli and Baxter-Jones, 1995). The results of this study determined that the pivotal age for the most injuries sustained was for rowers between the ages of 15- and 17-year-olds. Gender split determined that the age group with the highest injury report for boys was J16, with 71.5% of injuries, whereas female reports were highest in J15 rowers, owing 66.67% of total injuries. Considerations to support explanation why injury instances are higher in these age brackets include; maturation, sex-related differences, and burnout.

5.2.1 The Growing, Pubescent Athlete

Growth spurts in adolescence affect muscle strength to body mass ratio, thus prolonging periods of soft tissue exposure and vulnerability to injuries, particularly stress and strain-related (Hawkins and Metheny, 2001). Incomplete growth and maturation in younger athletes proposes cartilage tissue damage in developing musculoskeletal areas (Wilson and McGregor, 2014). In addition, Shanmugam and Maffulli, (2008) reported that during peak growth periods, biomechanical bone properties change, increasing susceptibility to sports injuries. This is supported in the findings of this study, where 71.5% of injuries in males occurred aged 16, with 66.67% of females sustaining injuries aged 15. This is endorsed by the earlier work of Sinclair (1973), who reported that girls often reach their peak body height and weight around the age of 15, whereas boys continue to grow until aged 18+, suggesting why these respective age groups are at the greatest risk of sports injuries. This provides reasoning as to why the results of this study found fewer reported injuries at either end of the age spectrum, either before puberty or after major physiological changes.

Whilst developing sexual characteristics, puberty is the period of an adolescent's life where physical growth occurs (Brown *et al.,* 2017). The results of this study reported the lowest number of injuries in those who measured 140-149cm tall, as demonstrated in **Figure 15**, whereas the highest reports of injuries were in females measuring 160-169cm, and in male rowers, those measuring 170-174cm and 180-184cm tall. During maturation, skeletal growth occurs prior to musculotendinous growth, resulting in muscle tightness and decreased flexibility (Cejudo *et al.,* 2020); in turn increasing injury risk, particularly in sportspeople. As recognised, J16s were at the greatest risk of injury accounting for 23.3% of total injury reports, demonstrated in **Figure 13**. The timing of puberty differs between individuals, including early and later-onset of maturation (Roemmich and Rogol, 1995). As a result, maturation and puberty should be managed on an individualist basis.

In addition to age, research into gender predispositions have taken the approach to consider differences in physiological structures, hormone imbalances and puberty influences in adolescents (Lin *et al.,* 2018). 803 females and 727 males agreed to take part in the injury surveillance programme, and the results determined that 56.66% of submissions were made by female rowers, 41.66% by males and the remainder did not identify a gender, as observed in **Figure 8**. The results implied that females are at a greater risk of rowing-related injuries compared to their male counterparts. These findings are consistent across rowing and general sports research (Smoljanovic *et al.,* 2009; Richardson *et al.,*2017). Although reports determined that only 3.75% of females and 3.3% of males reported an injury over the six-month period, on a larger scale these findings have the potential to be detrimental for junior rowing (**Figure 8**). As a result, if the impact of researching injury prevalence can help reduce injury rates from 3% to 2%, less juniors will sustain injuries reducing drop-out rates, reoccurring injuries, and fewer long-term health implications.

Puberty is highlighted as a predictor for the onset of injuries in teenage athletes across sporting research (Kelm *et al.,* 2004). Although females are more sensitive to reproductive changes, males experience testosterone surges, particularly from the age of 14 (Poncelet, 2020). As testosterone produces an anabolic effect, muscular hypertrophy occurs in turn improving strength and sports performance (Vingren *et al.,* 2014). Although testosterone has its benefits for sport, it can also induce tendon stiffness as a result of collagen turnover

(Hansen and Kjaer, 2016). Therefore, if not managed accordingly can cause muscular damage in the forms of tenderness, tears, strains, and ruptures (McHugh *et al.,* 1999). Research into the pubescent female by Maïmoun and colleagues (2014) highlighted growth and bone mass dysfunction amongst teenagers who had encountered pre-menstrual syndrome, placing them at increased risk of sports injury when engaging in intense training and competition programmes. When comparing gender to site of injury, females within this study sustained 20% more lower limb injuries compared to males as shown in **Figure 9**. Knee adduction movements increase within pubertal females when experiencing periods of rapid growth (Ford *et al.,* 2010). This suggests why female rowers are at a greater risk of knee injuries during puberty, as a result of "knocking knees" during the rowing stroke (Powell and Barber-Foss, 2000; Loës *et al.,* 2008). Further reasoning provided by Thornton *et al.,* (2017) attributed knee adduction, otherwise known as 'bowlegs', to incidents of iliotibial band syndrome, from compression on the iliotibial band creating friction between the lateral femoral condyle. Females were also at a greater risk of sustaining long-term injuries during post-pubertal years (Myers *et al.,* 2013), with an increased risk of non-contact anterior cruciate ligament injuries from knee laxity (Park *et al.,* 2009). Laxity within the patellofemoral joint is caused by an increase in oestrogen concentration (Hansen and Kjaer, 2016) thus, affecting the stability of the joint (Quatman *et al.,* 2008). In addition, Quatman speculated that laxity increases the risk of hypermobility in 33% of females, with additional looseness displacing the joint, often causing ruptures to surrounding patellar tendon.

5.2.2 Technical Differences

Gender discrepancies are not only existent between injury rates in rowers, but also in the way the stroke is performed, with evidence females and males' row differently, which can provoke the onset of various injuries (McGregor *et al.,* 2008). The results of this study determined that both genders followed suit of trunk injuries being the most common site, followed by lower limbs, as demonstrated in **Figure 9.** The work of Smoljanovic *et al.,* (2009) shows comparable results, with the lower back being the most common site of injury in both genders, followed by knees and then forearms/wrists. A thorough assessment of differences in rowing technique analysed by NG *et al.,* (2013) found that male rowers over-posteriorly tilted their pelvis, and over-flexed through their thoracic spine in comparison to females ($P < .05$). Alternatively, females were found to have significantly longer drive phases suggesting possible over-reaching at the catch, and over-extension at the finish (P = .001). Females also display greater hip and ankle range of motion, giving further suggestion as to why their stroke is longer, yet if not managed accordingly can place them at greater risk when catching under load or in a weaker position at the finish (Decker *et al.,* 2003). Likewise, risk of LBP differs between surveillance reports. NG *et al.,* (2014) found males to be at a greater risk of LBP with 65% of reports making up lumbar injuries, to 53% of females. Comparatively, Kosović and Marinović (2017) recorded 80% of injured females to have postulated LBP, in comparison to 45% males. These differences support the ideology that both genders may be exposed to different biomechanical stressors, thus requiring gender differences to be taken into consideration when analysing technical capabilities in reference to injuries. However, proposing a technical revisit to the catch position in order to reduce overreaching at the front end of the stroke causing compression of the lumbar spine, has the potential to draw benefits in the reduction of back pain for both genders (Morris *et al.,* 2000).

5.2.3 Managing Athletic Commitments and Burnout During Teenage Years

Recognised within the results of this study, 16-year-old rowers are at the greatest risk of injury attainment. The age of an adolescent embarking on GCSEs averages around 16 years old (Gill, 2010), undertaking examinations and vulnerable to high-stress environments. Across the country, immense pressure, and a culture of succession to obtain high exam grades has been adopted by students, schools, universities, and examination boards; placing undue stress on year 11 pupils (Roome and Soan, 2019). Research by Kerr and Minden (1988) analysed the impact of life-stressors on injury rates in adolescent athletes, reporting that stressful events significantly impacted both the rate of injury attainment and the severity of the injury itself. This is endorsed by the more recent research of Mann and Colleagues (2016), who reported more physical injuries during periods of high stress in collegiate American footballers. Upon reflection, external stressors need to be taken into consideration when analysing injury research, as well as academic stress being actively recognised by coaches when planning and delivering training sessions in terms of duration, purpose, and intensity (Hall, 2019).

5.3 Regional Differences, SES and Athlete Development

The results of the current study show that all ten regions submitted at least one report of an injury over the six-month reporting period. SES is often categorised by highest level of parental education, social resources, and combined annual family income (Schwartz *et al.,* 2003). Within this study, SES was determined by the postal code area of the rowing club location within its respective region. The four clubs with the most injury reports were located in the top 40% of the most deprived neighbourhoods in England. Traditionally, those from higher socio-economic backgrounds have more disposable income and leisure time to engage in physical activity (Ford *et al.,* 1991). However within this study, clubs from lower SES areas were at an increased predisposition to injuries instead. In addition, females from lower SES backgrounds were at an even greater risk of injury attainment in comparison to males. 16 female and 11 male injury reports were collated from the top 30% of the most deprived areas in England, attributing a total of 45% of injuries to have been sustained from athletes in low-SES areas. The impact of SES on an athlete's injury adherence arisen as a topic of interest during the proceedings of the research, with scope for future investigation into injury incidence, discussed in *6.0.*

<u>*5.3.1 Coaching Education and Support*</u>

Despite organisations like UK Sport investing in coach education (UK Sport, 2015), voluntary sports coaches make up 72% of the coaching workforce in England (North, 2009). In addition, many volunteer coaches do not receive adequate formal training, as a result of the cost of qualifications (Wiersma and Sherman, 2013). Additionally, volunteer coaches often possess an alternative job away from the club, and therefore cannot devote all of their time to each athlete. Although coaching force was not accounted for during the process of this study, Koester (2000) found that sports injuries can be attributed to improper technique or impractical conditioning when taught by volunteer coaches. This is supported by the work of Faigenbaum and Myer (2010), who discovered injury rates to be highest when sessions are unsupervised or coached by an untrained individual, whereas injury rates were lowest when age-related training guidelines were followed and taught by a trained professional. Regardless of coach education not being the only contributing factor to sports injuries, it is a preventative measure that can be managed with suitable training and education, in a bid to reduce the injury rates highlighted in the results of this study.

Within less-comprehensive clubs, Adler and Newman (2002) reported a higher number of athletes from lower socioeconomic income households, who already experience reduced availability to specialised healthcare resources. The highest reporting clubs for injury rates within this study were from the top 40% of the most deprived neighbourhoods in England, showing that clubs from lower income areas are at an increased risk of sustaining multiple injuries within their junior squads, posing a higher risk of injury rate. Within the club environment across the board, unless a club has a high-performance programme running within it, there is no access to wrap around care with in-house sports medical professionals or qualified strength and conditioning coaches, placing higher demand on coaches to co-deliver programmes and parents when supporting injury management (Walsh, 2020). In addition, rowers attending less-developed clubs within lower socioeconomic areas posed higher risk of traumatic injuries, potentially as a result of poorer quality and inappropriate equipment onsite (Macpherson *et al.,* 2010).

5.4 Reoccurrence of Rowing Injuries

The results of this study found that the risk of reoccurrence was 45.45% higher in male athletes compared to females. Female injuries reoccurred on 17.24% of occasions, whereas males demonstrated a 78.5% reoccurrence. Stanitski (1997) suggested females have already undergone maturation earlier, meaning that the risk is higher for males whilst still enduring hormonal imbalances. Moreover, males are at a greater predisposition to become frustrated as a result of time out of training from injury, inferring males may leave insufficient time to recover before returning to participation and therefore reinjure (Elliott, 2018). In addition, males and sport date back within cultural research into hegemonic masculinity. Building masculine identities is dominant within male sport, and time out from an injury highlights weakness, thus anticipating a speedier return to sports participation (Bramham, 2003). This suggests why 47% of reoccurring injuries happened within the first two months of recovery, as a result of rapid return to sport and insufficient healing of the injury sustained. In addition, the results within this study emphasised that 17-year-old rowers, had a 50/50 chance of sustaining another injury after the first one occurred. There is a minor increase in rate of reoccurrence as age increases, dropping again within J18 rowers before senior years. This further solidifies reasoning as to why injuries occur during periods of maturation, attributing the later teenage years to reinjury risks from pubertal changes and the culture of masculinity (Elliot, 2018l; Krajňák, 2020*)*.

5.4.1 Severity of Injuries Sustained

There are research complications when defining the severity of an injury, as severity may differ as a matter of opinion between sportspeople. Time taken to return to full sports participation, sustained periods of adaptive training and level of treatment received were all taken into consideration to determine each individual's reported severity within this study. 61.7% of injuries were classified as not severe, compared to 38.3% reporting severe injuries. When isolating injury severity by classification, 9 accounts of overuse injuries were classed as severe, to 21 less-severe overuse reports. As overuse injuries often start off as small niggles, they arise over multiple training sessions as opposed to one-off instances, thus reducing the perceived severity (Cumps *et al.,* 2007). The same number of traumatic injuries were reported as severe to not-severe. Whereas within those who did not determine an injury classification, almost double the number of injuries were reported as not severe. That being said, severe injuries only made up 38.3% of total injury reports, mimicking the work of Engebretsen *et al.,* (2013), who found that 65% of injuries sustained during the Olympic games were of a minimal severity, resulting in no time lost from training or competition. In addition, the severity of the injury sustained was variant depending on site of injury. Within the results of this study, head and neck injuries were determined by their severity based upon time out of training, whereas injuries determined to be of a lower severity were overcome with periodic stretching and home treatment. Lower limb injuries were determined as severe if; training had to be terminated, they could not reach full-catch extension without pain and being unable to complete everyday tasks post-training. Less severe cases meant adaptive training was adopted and injuries eased with home treatment and stretching. Trunk injuries were treated as severe where time out was over extended periods of time, or the athlete did not return and had to seek physiotherapy. Less severe instances adhered to reduced workloads, reverted from sweeping to sculling and used home pain-management techniques to treat injuries. Lastly, upper body injuries were determined as severe if months were taken out of training. Less severe instances were categorised by the injury occurring regularly, short periods of adaptive training, feelings of mild discomfort and altering session plans to reduce aggravation.

5.5 Consequences of Injuries in Junior Rowers

Attaining an injury imposes short-term setbacks for athletes, as a result of time out from training, or periods of adaptive training. Long-term implications and the reason for researching junior injuries can significantly impact on an athlete's future sporting success (Gang, 2013). Statistical evidence from Boykin *et al.,* (2013) reported that adolescent rowers with hip impingements correlated with a decreased return to rowing by 44%. Rowing is a highly competitive sport which is at times fostered too much into junior performance programmes, instead of highlighting participation and enjoyment which are key characteristics to promote long-term participation (Wall and Côté, 2007). Moreover, despite current research focusing heavily on elite rowers, it supports the notion that overtraining intensifies injury risks and drop-out, with athletes who drop-out regularly acknowledging overtraining with burnout. Not only is burnout associated with physical depletion, but also emotional exhaustion; both in turn reducing performance levels and increasing risk of injury (Calmeiro and Collsel, 2013). It is also linked with lack of recovery between sessions and places undue stress on the musculoskeletal system (Lehmann *et al.,* 1993). Common burnout causes include overtraining and regular competitions as opposed to skill development and the social benefits of sport (DiFiori *et al.,* 2014). Therefore, it is important when working with paediatric sporting populations, that consideration to the history of injuries, age and maturation level, sporting commitments, and physiological changes that may have triggered the injury is given (Emery, 2005).

Considering age and physiology, it is important to consider rowing styles as a predictor of injuries. Adolescence is a key transitional period, where athletes can progress from sculling into sweeping (Thornton *et al.,* 2016). In reference to **Figure 2**, it is vital not to introduce athletes to sweep rowing until the recommended age of J15. However, what it fails to identify is that each individual's maturation and physiological adaptations occur at different ages. Late-developers have the potential to be at an increased risk to injuries, if muscular structure is not yet fully developed (Hagerman, 1984). Sweep rowing requires a more dominant side of the body, leaving one side weaker than the other if not alternated therefore causing muscular imbalances (Aiken, 2014). Hosea and Hannafin (2012) supported this notion, suggesting that coaches should recognise the maturation level of each individual rower on their squad as opposed to one age class, before transitioning into sweep rowers.

Athletes who have sustained a sporting injury possess feelings of fear of vulnerability to future injuries (Houston *et al.,* 2017), apprehensive they may recur at a later date. Sports-related anxiety largely impacts return to participation, in particular in relation to fear of outcome (Bayles, 2016). In psychological terms, the Fear Avoidance Model emphasises the apprehension experienced by athletes who have attained an injury and fear recurring traumas thereon; taking into consideration location of injury, treatment required, age of athlete and whether the event had happened before (Markfelder and Pauli, 2020). If a rower demonstrates returning anxiety after experiencing an injury, not only are they more emotionally withdrawn from the sport, but at an increased risk of getting injured again (Toohey *et al.,* 2017). Furthermore, alongside being at a psychological disadvantage, physiologically muscular structures become weaker, tendons and ligaments may inflame more easily and biomechanical changes to sequencing and patterns of sporting movements place the athlete at greater risk of injury recurrence (Erickson and Sherry, 2017).

Finally, it should be acknowledged that receiving the incorrect rehabilitation from a severe injury can pose future health risks, suggesting why there is a drop-out rate after adolescence (Starr, 2017). Burland *et al.,* (2019) reported long-term health implications in athletes suffering traumatic knee injuries, including chronic pain, inactivity, and even potential disability. In addition, there are longer-term health risks within junior athletes who early-specialise in a sport, or part-take in multiple sports to a high-level (Caine, 2009). These outcomes include osteoarthritis and ACL injuries, commonly requiring medication, long-term physiotherapy or in more severe circumstances, demanding surgery (Maffulli *et al.,* 2010).

Chapter 6: Future Directions for Rowing Injury Research

6.1 Study Limitations

A common complication when researching into sports-related injuries, is the process of athlete's underreporting in fear of looking weak to coach-player perceptions, and to prevent having to take time out of training and competition (Hammond, *et al.,* 2011). Rowers not reporting their injuries to the coach or masking injuries is a common sports cultural complication (Complete Concussion Management, 2019; Vassallo *et al.,* 2019). Within higher level sport, access to physiotherapists and additional resources outside of the coaching environment are available to enable injury management. Unfortunately, within grassroot sport these resources are scarce, and without seeking external support are not available thus impacting on recovery periods and reporting of injury encounters (Hammond *et al.,* 2014). Furthermore at grassroot level, it is the participant's responsibility to determine training and performance commitments when injured, whereas the decisions are usually made for elite athletes in high-end sport (Bullock *et al.,* 2020). This places further undue pressure on athletes in clubs to not report injuries, to avoid making these decisions. Underplaying niggles over a period of time, coupled with insufficient rehabilitation, can cause long-term implications affecting sports performance delaying performance recovery, and manifest health interferences in later life (Bullock *et al.,* 2020). In addition to false reporting, Klesges *et al.,* (1990) indicated that within sports injury surveillance documents, there are always going to be errors with recall bias, overestimating hours of participation, coach's incompletion of responses, non-responders, invalid injuries, and problems relating to identification of populations at risk. All contributing factors implicate the validity and reliability of sports research and should be managed accordingly (Rudicel, 1988).

Considering problems that presented themselves during the research investigation, it was challenging to attain club buy-in, as out of 370 clubs that were contacted across England, only 9% agreed to take part. When analysing reasonings as to why higher uptake was not achieved, clubs with voluntary coaches expressed that additional stressors on top of everyday coaching would become burdensome on workload, where the time to fill in a reporting document could be utilised elsewhere (Potts *et al.,* 2018). In addition, there is a social stigma surrounding reporting injuries for individual clubs. Although publishing data was only recognisable by respective regions, clubs do not want the perception of being associated with high injury reports as they may feel like their coaching team or their programme will be scrutinised.

Lastly, the cohort of rowers within the research did not represent all regions of England. A large proportion of results were from Northern England rowing clubs, implying there was potential for selection bias having a stronger communication network with coaches from the North East. Using appropriate British Rowing networks and various social media platforms, reaching further afield clubs became more accessible, but results still favoured Northern clubs. In addition, club location did not necessarily represent the postal code area the rower was from. SES was drawn from a club's postal code area, and with rowing clubs often being further afield from each other, participants may travel into rowing clubs from different postal code areas from different socioeconomic brackets. Future research into SES and sports injuries should capture the data of each rowers' income, to accurately determine barriers and risks relating to finances.

6.2 Implications of SES on the Developing Athlete

Implicating future research, Bejar, (2013) proposes that an individual's income bracket effects how a person responds psychologically, emotionally, and physically to the onset of an injury rather than the impact on the injury rate. Financial priorities for families from low-income backgrounds rank food and clothing purchases to be of higher importance before paying for sports participation (Wright *et al.,* 2003). Moreover, there are additional financial implications if an athlete were to become injured and require sports-specific physiotherapy. When accessing NHS physiotherapy as a free service, there are often waiting lists and are run by non-sports specialist professionals; with the alternative solution to access a private sports physiotherapist. A study by Zuckerman *et al.,* (2017) found that return to school sport was quicker for American athletes who had access to private healthcare, suggesting that paying the premium to go private provides extensive support to ensure full recovery post-injury, whereas public insurance only covers basic healthcare improvements. Similar findings were reported within the UK, where Pike (2005) found that female rowers who sought NHS support over a two-year period testified the medical support to be inadequate. This was due to lack of medical advice, incompetent diagnoses and an over-reliance on prescribing medication as opposed to treating the problem. Consequentially, private healthcare within a specialist field comes at a cost which many households cannot prioritise generating disparities within low-income athletes, which could have a significant impact on injury reoccurrence and overall return to sport.

Competing time commitments from regular sports participation coupled with academic obligations has already been identified as a perpetrating factor of increased injury risk (Ryan, 2015). Another consideration, yet understudied topic, is the importance of managing education and a sport-life balance alongside achieving financial independence, particularly in athletes transitioning from secondary to tertiary education (Wylleman and Rosier, 2016). Many athletes aged 16+ must consider financial stability whilst balancing academia, personal commitments, and sporting pressures (Hamilton, 2018). Managing several burdens can become too much to cope with, often causing athlete burnout if pursued for long periods of time (Roderick, 2006; Moen *et al.,* 2015). In particular, those from lower SES backgrounds pose an increased threat from additional stressors, including time management and household income pressures (Bejar and Butryn, 2016). This is a result of increased dependency to work and provide familial support from working-age, despite other protruding commitments (Lerman, 2000; Madigan *et al.,* 2020). With greater understanding of the impacts both physiological and psychological burnout can have on athletes, due consideration should therefore be given to those from lower household incomes; though not depicting that athletes from higher income backgrounds can also suffer burnout-related injuries.

The impact of high-stressor environments has become developmental to existing research, to help recognise which factors within high-stress environments contribute to injury hazard. Mental fatigue can increase the risk of errors made due to; reduced alertness (van der Linden *et al.,* 2006; McCormick *et al.,* 2012), reduced energy impacting performance abilities (Macora *et al.,* 2009), and increase the risk of athlete injuries (Brent, 2018). This provides insight towards the findings of **Figure 20**, giving suggestion as to why traumatic injuries were considerably prevalent within the injury reports gathered, as making novel mistakes when fatigued is common. Recommendations by Gantois *et al.,* (2019) propose that athletes should avoid demanding cognitive-functioning activities before competition, for best performance outcomes and reduced risk of acute injuries. Despite recognising the importance of stress-management within an elite sportsperson's training regime, grassroot sport does not have the capacity to manage stress with each individual athlete, without national governing body support and specialist training (Knights and Ruddock-Hudson, 2016).

The effect a sports injury can have on an adolescent heavily depends on the risk of reoccurrence and the severity of the injury. Long-term implications of ongoing or severe sporting injuries can temporarily or permanently terminate training (Engebretsen *et al.,* 2013). Although a prospective study would be required to evaluate the long-term effects rowing injuries would have on future participation, it is important to consider the effects injuries have on short- and medium-term participation, in a bid to promote reduction in rates and lessen the probability of drop-out (Maffulli *et al.,* 2010).

Chapter 7: Conclusion

The purpose of conducting this study, was to assess injury incidence in adolescent rowers, and the factors associated. The study produced similar results as of those already present in current literature when considering anatomical location, age, gender, and the exposure of injuries. To summarise key findings, over the six-month surveillance period, 60 reports were filed. The highest number of reports came from Northern rowing clubs accounting for 65% of injury reports, despite having club representation from across all 10 regions of England, highlighted by British Rowing. Physiological reasoning was underpinned within the discussion, to offer suggestions such as why there were age-related differences within reported incidents, how gender and puberty may have impacted upon the results, how training can affect injury incidence and the implications the mechanics of rowing can have on the body.

The foundation of this research has the potential to increase interest into the injuries sustained by junior, grassroot rowers, and the associated physiological and sociological implications that may further impact injury rates. Recommendations can be given for rowing clubs to continue to surveillance injuries within their junior squads, as a documented record; useful to both the club for identifying injury risks, and to British Rowing when working on drop-out analytics. There is a lack of continuation of injury surveillance in junior rowing, resulting in insufficient evidence to inform on how best to support the development of junior rowers from all backgrounds, and all participation levels through to performance. Future research has the potential to explore SES of athletes, dietary considerations and drop-out as a longitudinal study. Moreover, additional research into junior injury incidence in rowers has the capacity to support the findings of this study and promote suitable interventions to reduce the occurrences of injury incidence. Lastly, for future studies, recommendations would be to simplify the injury surveillance document further, to ensure full results can be achieved with no blank questions, or further opportunity to probe for questions when injury responses are collated.

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Appendices

Injury Incidence and Prevalence Data in Junior Rowers

My name is Amy McCarthy and I am studying a Masters Research Degree at the University of Durham. I am also a Henley Royal Regatta Charitable Trust Coach for British Rowing. I am interested in researching into 'Injury Prevalence Data in Adolescent Rowers'.

Junior coaches from clubs and schools across the UK have been asked to fill in a consent form on behalf of their club, to share anonymous data based on their junior athlete's health and performance. This reporting document will cover a six-month period with the aim of helping differentiate between various injuries that adolescent rowers (up to racing age J18) may attain through their athletic career. Once data has been reported regarding injury rates, it provides a platform for future research into prevention of said injuries to increase participation rates and retainment of juniors through to seniors.

Reporting is expected to commence in May 2019 and terminate in December 2019. Upon completion of the consent form, in compliance with the University's ethical approval standards, clubs will be emailed the following documents stated below;

- Coaches information sheet
- Coaches privacy note
- Parental information sheet
- Parental and junior privacy note
- Later followed by the 6-month reporting document

The Google Form will entail a series of questions based upon one sole injury per athlete. Coaches will be asked to report the following;

- Gender of athlete
- Racing age of athlete
- Height of athlete
- Weight of athlete
- Hours per week of training the athlete encounters
- The date the injury occurred
- The site of injury (where on the body)
- Attainment of injury (during racing or training) including environment it was sustained in
- Classification of injury (multiple option question with in-depth descriptions)
- Mechanism of injury
- Whether it is a reoccurring injury
- Severity of injury
- Requirement of medical attention

Coaches will be required to fill in a new Google Form (taking approximately 3-4 minutes to complete) every time a junior athlete becomes injured in their squad during the designated time period. If one athlete sustains multiple injuries, each injury will be asked to be reported in isolation and treated as separate injuries. This exposure report form has been adapted from the work of Fuller et al., (2006) who conducted a consensus statement on injuries in football. These injury reports can either be self-acclaimed by both the athlete and coach or confirmed by a medical specialist.

If an injury report has already been filled in for an athlete and the same injury reoccurs later in the study, it should be reported as a separate form but stated that it is a recurrent injury. Coaches should not report previous injuries attained by athletes, unless it is still problematic when the study commences. If an injured athlete is still injured when the study finishes, it should be given consideration how long they will be out of training for in the future.

Regarding privacy, no athlete or club is to be named or identified upon publication of results. Instead, clubs and schools will be identified collectively as their respective regions as stated on the British Rowing website. All research is voluntary, and the club has the right to withdraw their data upon termination of the study or during their reporting period. Upon completion, clubs and schools can request a copy of the research and the right to further contact with any queries relating to the study.

All data will be stored on a password protected British Rowing Google platform on a protected personal laptop. Despite being stored through said platform, British Rowing will have no access to the data and will only have access to the completed report that clubs and schools may also have access to upon publication. No data will be stored by hard-copy and all raw data will be wiped.

Thank you for your time in completing this research for my master's degree. If you have any further questions regarding this Google Form, please contact me via email amy.l.mccarthy@durham.ac.uk or amy.mccarthy@britishrowing.org.

*Required

Email address *

Your email address

Rowing club name *

Your answer

Postcode of rowing club including region

Your answer

Name and email of main point of contact affiliated with junior group who will be reporting the injury data *

Your answer

Number of juniors currently at the club (approximately) *

Your answer

Number of male juniors within the junior squad *

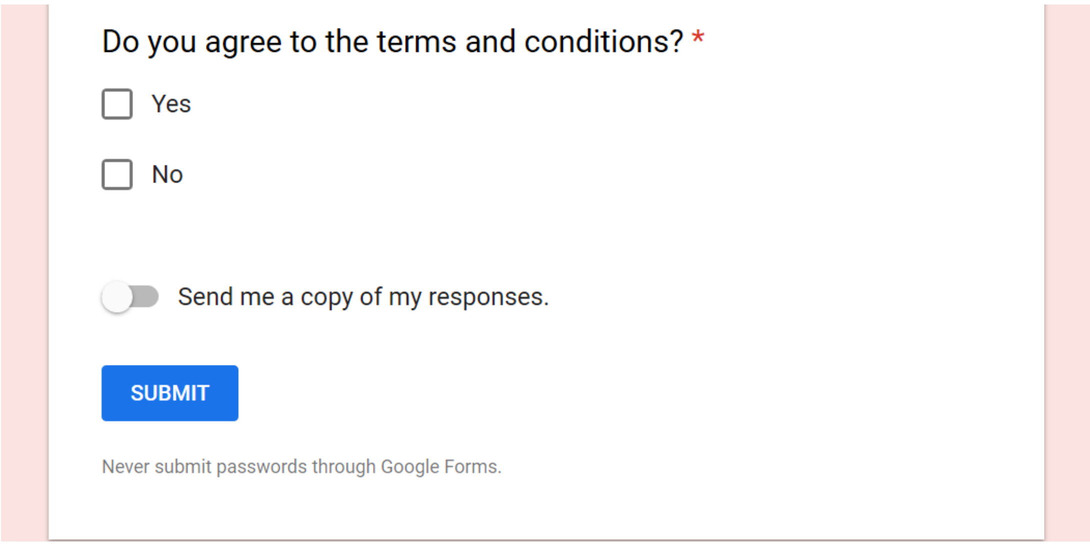
Your answer

Number of female juniors within the junior squad

Your answer

Terms and conditions

Upon completing this form, you have the right to withdraw from any research taken up until 2 weeks post-research (end of September 2019).
All data will remain anonymous and no club or athlete will be identified. Instead, they will be identified under their respective regions.
All clubs have the right to access the results once research is completed.
I understand that agreeing to the terms and conditions, I am supporting a masters proposal as well as providing injury prevalence data.


Do you agree to the terms and conditions? *

Yes

No

Send me a copy of my responses.

SUBMIT

Never submit passwords through Google Forms.

Appendix A: Consent form circulated to schools and clubs who wished to take part in research, to register interest through.

Injury Prevalence Data in Adolescent Rowers

Coaches information sheet

Thank you for agreeing to take part in my research project, affiliated with Durham University. Towards the end of 2018, I was assigned the post of Henley Steward Charitable Trust Coach for the Sunderland region with British Rowing. Previously I was a student volunteer coach at Durham University and before that a junior rower from the age of 13 at Tyne United Rowing Club.

This research will underpin a series of questions relating to injury prevalence data within junior rowers. British Rowing regulations request that any injuries sustained at a club should be recorded. Within this research, injuries will be reported and then analysed to determine prevalence data across the UK. This research will assist going towards a hopeful PhD project determining if there is an injury problem within junior rowing, and if so, appropriate intervention techniques to reduce the risk of injury in adolescents.

A junior coach representative from each club will be asked to fill in data within a reporting document every time a junior athlete (aged 18 and under) from their club becomes injured. This document will consist of a short series of questions mostly requiring one-word answers;

- Age of athlete
- Sex
- Height and weight
- Site of injury (where on the body)
- Cause of injury (in brief)
- Type of injury (soft tissue, joint or bone, head, neurological or not known)
- Acute or chronic injury (happened suddenly or a prolonged pain over time)
- Time off from training required (months, weeks, days or adaptive training)
- Years affiliated as a British Rowing member (approximately)

Coaches are asked to fill in this information over a period of six months (February-September) and report in the document every time an athlete becomes injured, even if it is a reoccurring injury. Six months allows for differentiation between data when looking at head season rowing and the transition into regatta season rowing.

To confirm your agreement to take part, please fill out the online Google Form and accept the terms and conditions to proceed with the injury audit.

https://docs.google.com/forms/d/e/1FAIpQLSe7iONK5HFLk9V8YjtQNL9shPmWn-SlcFQqUfVjdGWXn-alfw/viewform

Once you have agreed on behalf of your club and the junior group, coaches will be shared a Google Form which only myself and the coach in question have access to. All data is protected on a password restricted Google Account locked on a security coded laptop. This sheet will allow coaches to report information freely following the questions above as protocol. Each individual audit for juniors should take no more than 5 minutes. Coaches are asked not to use any identifiers when writing about athletes. Instead of using first names or surnames, coaches are asked to either use pseudonyms that only they can identify each junior, or a name code of initials which is unidentifiable to the researcher (e.g. ALM). Upon publishing of results, all pseudonyms or name codes will be removed to protect anonymity. Clubs will also not be identified by name but will be grouped with other codes from that region to analyse the region collectively. There is a scope within the research to identify socio-economic status as a factor to injury prevalence. But again, no clubs will be named or identified. No coaches email addresses will be retained in line with GDPR regulations. If a coach decides to opt out of research, they will receive no further communication.

Please note, if a coach does not feel comfortable reporting certain injuries, they have the right to withdraw individuals from the research. Especially if parents are not comfortable with the reporting procedures. The audit does not require any intervening to the juniors and is British Rowing protocol to note any injuries occurred within training and racing. There will be no repercussions in place if a club decides to withdraw their data or withdraw individual's data.

If there are any questions or concerns, please contact;

Key researcher: Amy McCarthy (amy.l.mccarthy@durham.ac.uk) or (amy.mccarthy@britishrowing.org)

Key supervisor: Karen Hind (karen.hind@durham.ac.uk)

Appendix B: Coaches information sheet.

Injury Prevalence Data in Adolescent Rowers

Coaches privacy note

Durham University have responsibilities under data protection legislations to provide individuals with information about how their personal data is processed and used. To process personal data fairly and lawfully, it is my obligation to inform you:

- Why we collect your data
- How it will be used
- Who it will be shared with

The privacy policy will also explain your rights in controlling your data, how we use you information and how to inform us about your wishes.

Data controller

The data controller is me, Amy McCarthy as the researcher. Personal data will be retained and disposed of upon completion of the research. Please contact me on amy.l.mccarthy@durham.ac.uk with any concerns regarding personal data protection.

Data protection officer

The Data Protection Officer is responsible for advising the University on compliance with Data Protection legislation and monitoring its performance against it. If you have any concerns regarding the way in which the University is processing your personal data, please contact the Data Protection Officer:

Jennifer Sewel (University Secretary)

Telephone: (0191 33) 46144

E-mail: university.secretary@durham.ac.uk

Consent

You have the right to be provided with information about how and why we process your personal data. Where you have the choice to determine how your personal data will be used, we will ask you for consent. Where you do not have a choice (for example, where we have a legal obligation to process the personal data), we will provide you with a privacy notice. A privacy notice is a verbal or written statement that explains how we use personal data, which in this instance is this document.

Whenever you give your consent for the processing of your personal data, you receive the right to withdraw that consent at any time.

Accessing your personal data

You have the right to be told whether we are processing your personal data and, if so, to be given a copy of it. This is known as the right of subject access. All coaches have the right to request a presentation or a copy of the research conducted post-completion of the assignment.

Right to rectification

If you believe that personal data we hold about you is inaccurate, please contact us and we will investigate. You can also request that we complete any incomplete data. Once we have determined what we are going to do, we will contact you to let you know.

Right to erasure

You can ask us to erase your personal data in any of the following circumstances:

- We no longer need the personal data for the purpose it was originally collected
- You withdraw your consent and there is no other legal basis for the processing
- You object to the processing and there are no overriding legitimate grounds for the processing
- The personal data have been unlawfully processed
- The personal data must be erased for compliance with a legal obligation

Once we have determined whether we will erase the personal data, we will contact you to let you know.

Right to restriction of processing

You can ask us to restrict the processing of your personal data in the following circumstances:

- You believe that the data is inaccurate, and you want us to restrict processing until we determine whether it is indeed inaccurate
- The processing is unlawful, and you want us to restrict processing rather than erase it
- We no longer need the data for the purpose we originally collected it but you need it in order to establish, exercise or defend a legal claim and
- You have objected to the processing and you want us to restrict processing until we determine whether our legitimate interests in processing the data override your objection.
- Once we have determined how we propose to restrict processing of the data, we will contact you to discuss and, where possible, agree this with you.
-

Research specific privacy note

Coaches are asked not to use any identifiers when writing about athletes. Instead of using first names or surnames, coaches are asked to either use pseudonyms that only they can identify each junior, or a name code of initials which is unidentifiable to the researcher (e.g. ALM). Upon publishing of results, all pseudonyms or name codes will be removed to protect anonymity. Clubs will also not be identified by name but will be grouped with other codes from that region to analyse the region collectively. There is a scope within the research to identify socio-economic status as a factor to injury prevalence. But again, no clubs will be named or identified. No coaches email addresses will be retained in line with GDPR regulations. If a coach decides to opt out of research, they will receive no further communication.

Please note, if a coach does not feel comfortable reporting certain injuries, they have the right to withdraw individuals from the research. Especially if parents are not comfortable with the reporting procedures. The audit does not require any intervening to the juniors and is British Rowing protocol to note any injuries occurred within training and racing. There will be no repercussions in place if a club decides to withdraw their data or withdraw individual's data.

Appendix C: Coach's Privacy Note.

Injury Prevalence Data in Adolescent Rowers Across the UK

Consent form

Durham University

Using an injury audit database completed by coaches with a series of pre-determined questions, we will examine the prevalence of injuries in adolescent rowers across a six-month period. This will assess;

- Age of athlete
- Sex
- Height and weight
- Site of injury (where on the body)
- Cause of injury (in brief)
- Type of injury (soft tissue, joint or bone, head, neurological or not known)
- Acute or chronic injury (happened suddenly or a prolonged pain over time)
- Time off from training required (months, weeks, days or adaptive training)
- Years affiliated as a British Rowing member (approximately)
-

I confirm that I have read and understood the Participant Information document for the above study and have been given the opportunity to ask questions.

I understand that my participation is entirely voluntary and that I am free to withdraw at any time during the research, up until 2 weeks after the research has been completed, without giving a reason. 2 weeks post-research gives significant due time to remove any data collected, but enough for the researcher to write about the results without fear of data withdrawal.

I agree to the results being published, however with the absence of any names of juniors or clubs but replaced with respective regions instead.

I agree to take part in the above study.

Participant's Signature: ______________________________

Participant's Full Name: ______________________________

Date: ____________

Researcher's Signature: A. McCarthy ______________________________

Researcher's Full Name: Amy Leigh McCarthy ______________________________

Date: 30/01/19 ____________

Appendix D: Athlete Consent form

Rowing Injury Audit

Parent information sheet

Thank you for agreeing to take part in my research project, affiliated with Durham University. Towards the end of 2018, I was assigned the post of Henley Steward Charitable Trust Coach for the Sunderland region with British Rowing. Previously I was a student volunteer coach at Durham University and before that a junior rower from the age of 13 at Tyne United Rowing Club.

This research will underpin a series of questions relating to injury prevalence data within junior rowers. British Rowing regulations request that any injuries sustained at a club should be recorded. Within this research, injuries will be reported and then analysed to determine prevalence data across the UK. This research will assist going towards a hopeful PhD project determining if there is an injury problem within junior rowing, and if so, appropriate intervention techniques to reduce the risk of injury in adolescents. This will provide long-term support for athletes to reduce injury adherence in junior rowers to assist prolonged rowing through adulthood.

A junior coach representative from each club will be asked to fill in data within a reporting document every time a junior athlete (aged 18 and under) from their club becomes injured. This document will consist of a short series of questions mostly requiring one-word answers;

- Age of athlete
- Sex
- Height and weight
- Site of injury (where on the body)
- Cause of injury (in brief)
- Type of injury (soft tissue, joint or bone, head, neurological or not known)
- Acute or chronic injury (happened suddenly or a prolonged pain over time)
- Time off from training required (months, weeks, days or adaptive training)
- Years affiliated as a British Rowing member (approximately)

Coaches will be asked to fill in this information over a period of six months (February-September) and report in the document every time an athlete becomes injured, even if it is a reoccurring injury. Six months allows for differentiation between data when looking at head season rowing and the transition into regatta season rowing.

The coach will agree to go forward with the research by 'opting in' via a Google Form. From there, coaches will be shared a Google Form which only myself and the coach in question have access to. All data is protected on a password restricted Google Account locked on a security coded laptop. This sheet will allow coaches to report information freely following the questions above as protocol. Each individual audit for juniors should take no more than 5 minutes. Coaches are asked not to use any identifiers when writing about athletes. Instead of using first names or surnames, coaches are asked to either use pseudonyms that only they can identify each junior, or a name code of initials which is unidentifiable to the researcher (e.g. ALM). Upon publishing of results, all pseudonyms or name codes will be removed to protect anonymity. Clubs will also not be identified by name but will be grouped with other codes from that region to analyse the region collectively. There is a scope within the research to identify socio-economic status as a factor to injury prevalence. But again, no clubs will be named or identified. No coaches email addresses will be retained in line with GDPR regulations. If a coach decides to opt out of research, they will receive no further communication.

Please note, if a coach does not feel comfortable reporting certain injuries, they have the right to withdraw individuals from the research. The audit does not require any intervening to the juniors and is British Rowing protocol to note any injuries occurred within training and racing. There will be no repercussions in place if a club decides to withdraw their data or withdraw individual's data. Opting out will be the parents' responsibility to inform the coach they will be doing so.

If there are any questions or concerns, please contact;

Key researcher: Amy McCarthy (amy.l.mccarthy@durham.ac.uk) or (amy.mccarthy@britishrowing.org)

Or your junior coach at your rowing club.

Appendix E: Parent information sheet.

Junior injury audit

Parents privacy note

Durham University have responsibilities under data protection legislations to provide individuals with information about how their personal data is processed and used. To process personal data fairly and lawfully, it is my obligation to inform you:

- Why we collect your data
- How it will be used
- Who it will be shared with

The privacy policy will also explain your rights in controlling your data, how we use your information and how to inform us about your wishes.

Data controller

The data controller is me, Amy McCarthy as the researcher. Personal data will be retained and disposed of upon completion of the research. Please contact me on amy.l.mccarthy@durham.ac.uk with any concerns regarding personal data protection.

Data protection officer

The Data Protection Officer is responsible for advising the University on compliance with Data Protection legislation and monitoring its performance against it. If you have any concerns regarding the way in which the University is processing your personal data, please contact the Data Protection Officer:

Jennifer Sewel (University Secretary)

Telephone: (0191 33) 46144

E-mail: university.secretary@durham.ac.uk

Consent

You have the right to be provided with information about how and why we process your personal data. Where you have the choice to determine how your personal data will be used, we will ask you for consent. Where you do not have a choice (for example, where we have a legal obligation to process the personal data), we will provide you with a privacy notice. A privacy notice is a verbal or written statement that explains how we use personal data, which in this instance is this document.

Whenever you give your consent for the processing of your personal data, you receive the right to withdraw that consent at any time.

Accessing your personal data

You have the right to be told whether we are processing your personal data and, if so, to be given a copy of it. This is known as the right of subject access. All coaches have the right to request a presentation or a copy of the research conducted post-completion of the assignment.

Right to rectification

If you believe that personal data we hold about you is inaccurate, please contact us and we will investigate. You can also request that we complete any incomplete data. Once we have determined what we are going to do, we will contact you to let you know.

Right to erasure

You can ask us to erase your personal data in any of the following circumstances:

- We no longer need the personal data for the purpose it was originally collected
- You withdraw your consent and there is no other legal basis for the processing
- You object to the processing and there are no overriding legitimate grounds for the processing
- The personal data have been unlawfully processed
- The personal data must be erased for compliance with a legal obligation

Once we have determined whether we will erase the personal data, we will contact you to let you know.

Right to restriction of processing

You can ask us to restrict the processing of your personal data in the following circumstances:

- You believe that the data is inaccurate, and you want us to restrict processing until we determine whether it is indeed inaccurate
- The processing is unlawful, and you want us to restrict processing rather than erase it
- We no longer need the data for the purpose we originally collected it but you need it in order to establish, exercise or defend a legal claim and
- You have objected to the processing and you want us to restrict processing until we determine whether our legitimate interests in processing the data override your objection.
- Once we have determined how we propose to restrict processing of the data, we will contact you to discuss and, where possible, agree this with you.
-

Research specific privacy note

Coaches are asked not to use any identifiers when writing about athletes. Instead of using first names or surnames, coaches are asked to either use pseudonyms that only they can identify each junior, or a name code of initials which is unidentifiable to the researcher (e.g. ALM). Upon publishing of results, all pseudonyms or name codes will be removed to protect anonymity. Clubs will also not be identified by name but will be grouped with other codes from that region to analyse the region collectively. There is a scope within the research to identify socio-economic status as a factor to injury prevalence. But again, no clubs will be named or identified. No coaches email addresses will be retained in line with GDPR regulations. If a coach decides to opt out of research, they will receive no further communication.

Please note, if a parent does not feel comfortable reporting their child's injuries, they have the right to withdraw individuals from the research. The audit does not require any intervening with the juniors and is British Rowing protocol to note any injuries occurred within training and racing. There will be no repercussions in place if a club decides to withdraw their data or withdraw individual's data.

Appendix F: Parent Privacy Note.