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Evaluation of Injury Nature, Frequency, Mechanism and Population Demographics from a Global Women's Rugby Survey

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Abstract

The unprecedented increase in female participation in sports, particularly rugby union, necessitates a thorough comprehension of injury risks specific to female athletes. Traditionally, sports and exercise research has centred around males, leading to the development of insights and guidelines derived from male-centric data being applied to female athletes. This approach has resulted in a lack of customised injury prevention strategies for female athletes, despite well-documented influence of biological, anatomical, and physiological sex differences on sports performance, injury mechanisms, and risk. Existing literature has already demonstrated that females face a heightened risk of head-neck and knee injuries due to variations in underlying anatomy, biomechanics, and endocrinology. To address this data gap, this study aimed to collect data on the injury incidence, type, and location within a global female rugby population. Individual variables including height, body mass, starting age, experience, competition level, and playing position were also investigated as potential injury risk factors. This was done to identify areas of future focus for the development of effective female-specific injury prevention strategies.

An open, cross-sectional global survey for women rugby union players was published in 2020, with a maximum of 149 single and short answer questions. Data collected from the responses provided were then assessed and professionally translated to be statistically analysed. This study focused on responses relating to anthropometrics, starting age, experience, highest level of competition, and playing position and how these may affect the self-reported injuries that were included in the participant's responses. Whilst also trying to build an overall picture for the injury profiles of female athletes.

A total of 1,594 participants from 62 countries completed the survey overall (age 27± 6 years; height 1.66 ± 0.07 m; body mass 74 ± 15 kg). Of the 1594 participants, 1465 were deemed to have met the injury response criteria and were subsequently included in the analysis. 6,829 injuries were reported and classified into 147 different injury types. The top five most frequently reported injuries accounting for 48.7% of the total injury incidence, with ankle sprains, concussion, finger, and nose fractures, and then ACL tears collating the top five most reported injuries.

Significant differences were found in the incidence, type, and location of injuries sustained when looking at different risk factors. Differences were also found in the types of injuries sustained, when compared to literature reporting male orientated data across various levels of competition.

By beginning to highlight that female rugby union players have different injury profiles to that of their male counterparts, more research is needed to be carried out to help gain a greater understanding of injury risk in female rugby union athletes. By creating sex specific injury prevention protocols, this in turn would help deliver a safer environment for the females participating in rugby, and wider sport.

Declaration and Statements

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Chapter 1: Introduction

1.1 The Rise of Female Participation in Rugby and The Inherent Gender Data Gap

Rugby union (rugby) is a physically demanding and highly tactical team sport that originated in England in the early 19th century (Malcolm, Sheard, & White, 2000). Rugby has been dominated by male participation for much of its history. The women's game is the sector of rugby with the fastest participation growth, with an estimated 2.8 million active female players as reported by World Rugby in 2018, growing by 28% per year (World Rugby, 2019). As of 2021, the significant growth was still evident, with approximately one-third of the global rugby playing population comprising of women and girls (World Rugby, 2021). The 2021 women's Rugby World Cup (played in 2022 due to COVID-19), achieved record crowds. The final, played between New Zealand and England, was held at New Zealand's iconic Eden Park in front of a sold-out crowd of 42,579 (Grey, 2022). This highlights the increasing popularity and recognition of women's rugby as a competitive and exciting sport.

Despite the increasing participation of females in rugby, there remains a significant underrepresentation of women in the scientific literature pertaining to the sport. A growing body of research also suggests that gender and sex differences may render the generalisation of male-derived research findings to female athletes to be ineffective and potentially hazardous (Black, Sergio, & Macpherson, 2017; Bradley, Board, Hogg, & Archer, 2020; McGroarty, Brown, & Mulcahey, 2020; Stemper et al., 2008). One example of this is the utilisation of broad definitions like 'rugby union players' in studies that do not encompass female athletes in research cohorts, yet the resulting findings are applied universally to all rugby-playing populations. Such practices can have detrimental effects on the safety and injury prevention strategies for female rugby athletes. (Hendricks et al., 2020). There is growing evidence that sex-specific research is required in many domains (Costello, Bieuzen, & Bleakley, 2014). Specifically relating to rugby, there is a notable amount of research on injuries in men's rugby since its professionalisation in 1995, whilst very little attention has been given to the women's game (West et al., 2022). This has resulted in a limited understanding of the distinct injury risks faced by female rugby players, as well as the effectiveness of existing male-derived injury prevention strategies, such as the *Activate* program (Attwood, Roberts, Trewartha, England, and Stokes 2017) for female players. Of the small number of female-focused studies, Williams et al., (2021) reported substantial differences in head impact kinematics between male and female university rugby players. These authors concluded that their findings did not support the generalisation of androcentric injury prevention data to female players. They further cited the importance of considering anthropometric dimorphisms when applying androcentric injury models to females, particularly that of the cervical spine in the context of sport-related brain injuries. The increased vulnerability of females to cervical injuries and concussions (Solomito, Reuman, & Wang, 2018) highlights the necessity for sex-specific training and equitable playing time to establish training and injury procedures that improve the safety of female players. To do this, an objective, female-specific evidence base for training modalities and injury epidemiology is required.

1.2 Current Literature Findings on Increased Injury Risk for Females in Sport, Based on Dimorphic Differences.

The significance of sex dimorphisms regarding injury mechanics and aetiology was initially highlighted in studies relating to automobile crashes (Stemper, Yoganandan, & Pintar, 2003). These dimorphisms can impact the type, severity and frequency of injuries sustained, when applied in comparable scenarios (Bretzin, Covassin, Wiebe, & Stewart, 2021).

1.2.1 The Neck and Spine

The female cervical spine, for instance, exhibits greater vulnerability to whiplash and reduced ability to withstand inertial forces compared to males (Stemper, Yoganandan, & Pintar, 2003). Consequently, females experience higher levels of head displacement and acceleration during vehicle collisions (Caccese et al., 2017; Stemper et al., 2008).

In the context of rugby collisions, this poses a significant safety concern for female rugby players, especially when outdated injury guidance is considered (Williams et al., 2021). With the prevalence of concussions on the rise, accounting for 19% of all injuries in the women's Premiership rugby (Kemp et al., 2018), it is crucial to understand and address these anatomical and physiological differences. Developing appropriate training and injury prevention strategies that specifically consider these differences is of utmost importance.

1.2.2 Anterior Cruciate Ligaments

The game of rugby union involves many physical and skill-based aspects, with sharp changes of speed and direction being one of them. There is a vast amount of literature that has highlighted a greater risk of sustaining anterior cruciate ligament (ACL) injuries in contrast to their male counterparts for the same cutting and landing sports. Arendt & Dick, (1995) highlighted a four to six times greater incidence in Basketball and Football for females compared to their male counterparts. Initial research by Hewett, Myer, & Ford, (2006) acknowledged the need to understand underlying mechanisms that directed the sex-specific disparity in ACL injuries. More recently Mitani, (2017); Yu, Lowe, Griffin, & Dong, (2020) concluded that greater angles of internal rotation of the hip joint which are found more commonly in females, lead to a greater risk of ACL injuries. This example of highlighting dimorphic differences has led to gender specific prevention and training strategies for these areas of increased risk. Which in turn allows for a safer environment for females participating in sports once dominated by men.

1.3 Thesis Aims and Objectives

To address this gap in knowledge and inform sex-specific injury prevention strategies, there is a demand for more research focused specifically on injury risk in women's rugby. This research can help identify the most effective injury prevention strategies for women's rugby players, as well as improve the overall safety of the sport for all players. A global women’s rugby union survey was undertaken by a collaborative academic group in 2020, during the COVID-19 lockdown (Brown et al., 2023). Participants answered a total of 149 multiple choice and short answer questions on topics including playing history, training practices, demographics, and health-related issues. Of specific relevance to this thesis, participants were asked to document any injuries they had sustained during rugby activities, and if they were able, the mechanism by which these injuries occurred. Based on these data, the primary aim of this thesis was to understand:

- The composition (type, location, frequency) of injuries sustained by women rugby players through this self-reporting survey.
- The most common types of injuries sustained and any trends.
- The mechanism of injury occurrence.
- Areas of concern and the reasons as to how and or why these differences are occurring.
- How females may be able to reduce the risk of injury in the future.
- The results of this research will provide important insights into the injury risks faced by female players and inform the development of evidence-based injury prevention strategies tailored to this population. Therefore, the purpose of this thesis is to conduct a comprehensive analysis of injuries reported by women rugby players in a 2020 global survey.

1.4 Thesis Chapter Structure

Chapter 2: Literature Review

A review of literature related to the issues presented in Chapter 1 are found in Chapter 2. A brief history of women's rugby is outlined in Chapter 2.1. Chapter 2.2 explores current injury research and prevention strategies in rugby union and how themes within in this area are a part of a wider theme relating to the sex and gender gap in sports medicine. Chapter 2.3 explores the physical dimorphisms highlighted in literature between males and females. This chapter specifically explores the broader anatomical dimorphisms and takes a more in depth focus on the neck and spine morphology. The real-world implications of the dimorphisms explored in chapter 2.3 are summarised in chapter 2.4 focusing on non-sporting and sporting implications.

Chapter 3: Methodology

The background, development, and structure of the survey used in the thesis, along with participant and ethical approval are presented in Chapter 3.1. Chapter 3.2 outlines the data processing methods used in the study. It focuses on data cleaning and processing categorisations, data analysis and injury classifications used in the data cleaning. Chapter 3.3 then outlines the methods of statistical analysis used to explore the secondary aims of the thesis.

Chapter 4: Results

The results of this thesis with the statistical analysis are outlined in Chapter 4. Chapter 4.1 outlines the participant demographics of those involved in study. The anthropometrics and playing level of the demographic were reported in Chapter 4.2. The reported injury patterns of the demographic were also reported in Chapter 4.2. Overall injury demographics were reported in Chapter 4.3. Chapter 4.4 assess the effect of playing level on the injury epidemiology of the study demographic. Chapter 4.5 assess the effect of height, body mass, starting age, and experience on injury type and incidence. Whilst Chapter 4.6 assess the effect of those variables mentioned in chapter 4.5 on the location of the injuries that occur.

Chapter 5: Discussion

The results produced in this study are interpreted and discussed with reference to existing literature in Chapter 5. The methodical limitations and recommendations for future research are outlined also.

Chapter 2 Literature Review

2.1 A Brief History of Women’s Rugby Union

Rugby is historically a male-dominated sport that values physical strength and toughness (Clarke, Anson, & Pyne, 2016; Heyward, Nicholson, Emmonds, Roe, & Jones, 2020; Roe, Halkier, Beggs, Till, & Jones, 2016; Sheppy et al., 2020). The early emphasis on amateurism and elitism made it inaccessible to working-class individuals and women (White, 2004). This began to change in the 20th century with the formation of women’s teams in England and New Zealand (Joncheray, 2021). These teams faced significant opposition from the rugby establishment, however, with many officials believing that women were not suited to the physical demands of the sport (Collins, 2009; Vamplew, 2015). In recent years women’s rugby has gained significant popularity, challenging the perception of rugby as a sport exclusively for men (Mogaji, Badejo, Charles, & Millisits, 2020). Participation in the women’s game is the fastest growing sector of rugby globally, rising by 28% per year (World Rugby, 2019), and is now played in over 80 countries. The Women’s Rugby World Cup is held every four years, and the inclusion of rugby 7’s for both men and women in the Olympics has also helped to raise the profile of the sport (Goodale, Gabbett, Tsai, Stellingwerff, & Sheppard, 2017).

Despite many positive developments, there are still significant disparities between men's and women's rugby. Women's rugby is often underfunded, with lower levels of sponsorship and media coverage compared to men's rugby (Bowes, Lomax, & Piasecki, 2020; Mogaji, Badejo, Charles, & Millisits, 2020). There is also a significant pay gap between male and female rugby players, with female players often receiving significantly less compensation for their efforts (Bowes, Lomax, & Piasecki, 2020; Mogaji, Badejo, Charles, & Millisits, 2020). A lack of funding in women’s rugby consequently limits the medical provision available to the participating athletes. This limits the quality of the data collected during injury surveillance and in turn, negatively impacts the guidance given to help reduce injury risk in female athletes (Greenwald, Chu, Beckwith, & Crisco, 2012).

2.2 Rugby Union Injuries

2.2.1 Sex and Gender Data Gap in Rugby Injury Research

Due to the high-contact nature of rugby, it carries a substantial risk of injury (Williams, Trewartha, Kemp, & Stokes, 2013). While there is a significant body of research on injuries in men's rugby union, there is a lack of information regarding the specific injuries sustained by woman players. This gap in knowledge is concerning, given that the physical differences between male and female players may result in distinct mechanisms of injury (Williams et al., 2021). Male rugby players are taller and heavier than female players, with an average height and body mass of 1.87 m and 103.4 kg for the Men's England squad (n = 37) partaking in the six nations in 2024 ("RFU," n.d.-a) , compared to 1.71 m and 80.7 kg for the Women's English red roses taking part in the 2024 six nations (n = 33) ("RFU," n.d.-b). Males typically exhibit significantly greater muscle mass and upper and lower body strength than female players (Bartolomei, Grillone, Di Michele, & Cortesi, 2021). This size difference can impact the style of play and required skills in the sport, with males having an advantage in physical aspects of the game such as scrums and tackles. Men's and women's rugby share the same rules and objectives but differ in playing style and physical characteristics. Male players rely more on physical strength and speed, while female players focus more on technique and tactical play, according to a study by (Nolan, Curran, Brady, & Egan, 2023). These authors reported male players to engage more in high-intensity collisions and physical confrontations, while female players adopted a strategic approach to the game (Hughes, Barnes, Churchill, & Stone, 2017).

Numerous factors increase the risk of injury in rugby, including player age, playing position, and level of competition. Studies have found that male players are at a higher risk of injury than females due to differences in physical size and strength compared to their male counterparts. For instance, male players have been reported to have a higher body mass index (BMI) than females, which may increase the risk of musculoskeletal injuries (Fuller et al., 2015). Furthermore, the contact nature of the sport puts male players at a higher risk of collisions and tackles, which are known to cause injuries.

2.2.2 The Sex and Gender Gap in Sports Medicine and Rugby

Despite comprising 49.6% of the global population (World Bank Open Data, 2019), females are vastly underrepresented in medical research (Cowley, Olenick, McNulty, & Ross, 2021). Historically, medical literature has been androcentric; based on the ‘default male’ body (Cowley, Olenick, McNulty, & Ross, 2021), which has led to a lack of understanding of female-specific anatomy, morphology, and disease treatment (Marts & Keitt, 2004). Much of the existing sport and exercise science guidelines were developed using male-derived data that was extrapolated to females (Sims & Heather, 2018). There is still a lack of female-specific studies in sports and exercise science, despite the shrinking gender disparity in involvement in these activities. (Costello, Bieuzen, & Bleakley, 2014) concluded that women were still significantly underrepresented in the top three publishers in sport and exercise research. Cowley et al., (2021) further developed the findings of Costello, Bieuzen, & Bleakley, (2014) with it appearing that the total number of female participants and female-specific studies within sport and exercise science research remaining consistent over the last decade.

Considerable physical disparities in the response to exercises have been found by numerous authors (Bauman, Ray, & Joseph, 2017; Bruinvels et al., 2016; Mendiguchia, Ford, Quatman, Alentorn-Geli, & Hewett, 2011). In the context of these findings, the ongoing prejudice in the sport and exercise literature is cause for concern. The ramifications of androcentric research are significant and far-reaching, potentially resulting in incorrect medical diagnoses and inadequate treatment recommendations for females (Berger et al., 2006). The insufficiency of these recommendations has become apparent in the field of rugby, where the guidelines for return to play state a period of 7-14 days for adults without considering gender differences (West et al., 2021). This lack of differentiation is worrisome, especially considering the findings of D'Lauro et al., (2018) who reported that females have a longer mean return to play time from a concussive event, averaging a 35.5-day return compared to a 24.7 day return for their male counterparts. McGroarty, Brown, and Mulcahey (2020) published a systematic review of the literature surrounding return to play times for males and females and concluded that females endured longer return to play times. By not differentiating between the sexes with regards to treatment recommendations, a growing body of research have suggested that androcentric generalisations are ineffective and even dangerous (Black, Sergio, & Macpherson, 2017; Bradley, Board, Hogg, & Archer, 2020; McGroarty, Brown, & Mulcahey, 2020; Stemper et al., 2008).

2.2.3 Injuries in Rugby Union

Common injuries include concussions, fractures, dislocations, and ligament tears (King et al., 2019). Recent studies conducted by Kemp et al., (2021) England RFU produced the England Professional (Men's) Rugby Injury Surveillance Project 2019/2020 (From here on out known as PRISP followed by the year of report 19/20) and Women's Rugby Injury Surveillance Project 2020/2021 (From here on out known as WRISP followed by the year of report 20/21). Both reports targeted injury surveillance in the premiership and English national team athletes. Sex differences between the two reports were identified. The PRISP 19/20 reported that for both premiership and national team athletes, concussive injuries had the greatest incidence, with hamstring injuries having the highest incidence among premiership athletes. The WRISP 20/21 report, however, identified knee sprains and ligament injuries to have the highest incidence in premiership athletes during both matches and training. In English national team athletes, neck related injuries had the highest incidence in during matches, and ankle ligament / sprains during training.

Considering the PRISP 19/20 and WRISP 20/21 findings, measures have been put in place to reduce the risk of injury, including rule changes, and improved medical management in these elite populations (Barden, Bekker, Brown, Stokes, & McKay, 2020). The introduction of laws prohibiting dangerous tackles has reduced the incidence of head and neck injuries is an example of this (Stokes et al., 2019). Additionally, advances in medical technology and sports medicine have improved the management of injuries, allowing players to recover more quickly and safely (Rippe, 2010; Stevenson & Thompson, 2014). Despite the advances in medical technology and identification and addressing of the sex and gender gap in research, there is a lack of differentiation between male and female injury prevention protocols.

While a limited number of women's rugby injury studies exist, a higher prevalence of injuries in male rugby players compared to females. Yeomans et al., (2021) found that in Irish amateur rugby players, males had a higher overall injury rate (49.1 per 1000 player-hours) than female players (35.6 per 1000 player-hours). The most common types of injuries in male players were head and neck injuries, followed by shoulder injuries, while female players had a higher proportion of knee and ankle injuries after the head and neck (Yeomans et al., 2021). It must be noted that this study only included amateur athletes. Williams, Trewartha, Kemp, & Stokes, (2013) reported incidence rates of 81/1000 playing hours in professional male athletes. There is limited research providing injury demographics for female athletes. As a result, it is currently difficult to make meaningful comparisons. The lack of data makes it challenging to fully understand injury patterns and develop effective injury prevention strategies for female athletes.

2.2.4 Prevention Strategies

Prevention strategies whilst abundant for males, are found to be sparse in literature in relation to females. Whilst limited, there is evidence to support female specific injury prevention programmes that have reduced injuries in female athletes.
Myklebust et al., (2003) conducted a training programme for female handball athletes from division one-three across three seasons. The five-phase training programme focused on developing neuromuscular control and planting and landing skills. When compared to the first season which was used as a control season (No training intervention), the second and third season saw a reduction in ACL injuries sustained (29 sustained in the control season, 17 in season two and 13 in season three).

In relation to injury prevention in rugby, various strategies have been proposed, including rule changes, protective equipment, and injury prevention programmes. Particularly, injury prevention programmes that focus on neuromuscular training and strength conditioning have been shown to reduce the risk of injury in both male and female players (Rössler et al., 2018). A particular example of these strategies is the *Activate* injury prevention exercise programme which provides evidence for a 26-40% reduction in soft tissue issues: with a 29-60% reduction in concussions (Barden, Hancock, Stokes, Roberts, & McKay, 2022). The *Activate* programme was specifically designed by Hislop et al., (2017) as a prevention strategy to reduce match injury outcomes, including concussion. One limitation surrounds the use of only male derived data for these strategy developments. Williams et al., (2021) provided evidence to suggest that female rugby players have a 47% reduced neck strength compared to their male counterparts, at the university level. Based in part on these findings, World Rugby constructed a *Tackle Ready* programme that promotes confidence, physical competence, and safety in the contact area. However, the implementation of these programmes may differ between sexes due to physiological and biomechanical differences. Considering the evidence produced by Williams et al., (2021), World Rugby then introduced *Contact Confident* which focuses on activities such as: mobility, rolling, falling, and landing; deep neck stabilisation; neck strengthening; head reaction. These activities have been identified as important in mitigating against injury and they are especially important in the women's game where the injury mechanisms for concussion are different to the men's game.

2.3 Physical Dimorphisms Between Sexes and Underlying Injury Risk

2.3.1 Anatomical Dimorphisms

Throughout the 20th and 21st centuries, the scientific community has advanced the understanding of the human species and its evolution. As in many animal species, humans display sexual dimorphism in body composition from as early as foetal development yet is most primarily evident during the emergence of puberty (Wells, 2007). Sexual dimorphism has been defined as: '*the condition in which two sexes of the same species exhibit different characteristics beyond the differences in their sexual organs'* ("4.9: Sexual Dimorphism," 2016). These characteristics include musculoskeletal, lipid metabolism and human voice pitch between sexes. From the time of Aristotle to Darwin and beyond, a significant body of literature has aimed to comprehend and elucidate the emergence and evolution of sexual dimorphism in humans and other species. However, the practical application of these characteristic differences to the societal structures within our own species has remained comparatively restricted. These differences have become increasingly evident as society has begun to bridge the gap in gender disparity in the last quarter of the 20th century leading into the 21st, especially in relation to the rising participation in female sport.

2.3.2 Spinal Morphology

Evolutionary Accommodation

There is a wide variety of functions associated with the spinal column, with the importance focusing on providing stability and protection to major neurological structures such as the spinal cord and exiting nerve roots (Scataglini & Paul, 2019). Furthermore, it also facilitates mechanical load distribution between the upper and lower extremities (Scataglini & Paul, 2019). Segmental mobility and stability of the spine result in unique stress demands across multiple planes of axis in turn predisposing the spine to elevated levels of stress and potential injury. From an evolutionary standpoint, spinal sex differences have been found and attributed to the accommodation for load-bearing adaptations during bipedal pregnancy (McConnell et al.,1995).

Pregnancy in humans results in a modification of abdominal mass, with a potential increase of up to 31% (6.8kg) (Jensen, Doucet, & Treitz, 1996). Consequently, this shifts the centre of mass anteriorly, increasing the amount of force placed upon the lumbar spine and hips. These changes in abdominal mass are counteracted by the surrounding spinal, hip, trunk, and gluteal muscles. This can, however, lead to fatigue and increased risk of spinal injury due to sustained muscle activation (Oxland, 2016). In addition to physical changes, biomechanical and equilibrioception changes can also occur, with both balance and gait patterns adapting to the new abdominal mass (Yu, Chung, Hemingway, & Stoffregen, 2013). The physical, biomechanical and equilibrioception changes result in an increased risk of falling. The increased step time and step width coincide with the increasing speed and amount of postural sway (McCrory, Chambers, Daftary, & Redfern, 2010). When falls occur, there is a greater inherent risk of an emergency occurring in 40% of women which can cause but are not limited to head injuries, fractures, or miscarriage (Curet et al., 2000). Despite the increased risk of falls during pregnancy, Mei, Gu, and Fernandez (2018) found that females who were four months post-partum, their gait characteristics were similar to non-pregnant individuals. This suggests that the increased risk of falling is limited to the pregnancy period and does not have long-term effects on the risk of falling. By altering spinal anatomy to accommodate for bipedal pregnancy, the risk of injury inherently increases because of a decrease in spinal column stability. The occurrence of pregnancy serves as a fundamental basis for distinguishing between injury risks in males and females, as individuals who are biologically male from birth are incapable of experiencing pregnancy. These pronounced distinctions underscore the importance of assessing injury mechanisms and risks in a sex-specific manner.

Spino-Pelvic Alignment

Spino-pelvic alignment plays a pivotal role in the prevention of spinal deformities, so much so, reference values have been described for both asymptomatic adults (Boulay et al., 2006) as well as children (Marty et al., 2002). Janssen, Drevelle, Humbert, Skalli, & Castelein, (2009) provided three-dimensional analysis of differences in the spine-pelvic alignment. These authors reported that females are more dorsally inclined (11-degree inclination) compared to their male counterparts (8-degree inclination) from the first thoracic vertebrae to the fifth lumbar vertebrae (T1-L5). In turn, a higher degree of dorsal inclination signified that females are less rotationally stable; especially under certain conditions such as growth, which increased the risk of onset in certain spinal disorders (Janssen, Drevelle, Humbert, Skalli, & Castelein, 2009). Studies have also noted that scoliosis is a complex, three-dimensional condition that relates to deformation in the frontal, sagittal, and transverse plane. Increased dorsal angles and loading in the transverse plane causes increased rotation in the thoracic-lumbar spine. Asymmetric loading of the vertebrae then would lead to asymmetric growth in all three planes of the vertebrae, resulting in a progressive scoliotic deformation of the spine (Kouwenhoven et al., 2007). By identifying these differences and being able to differentiate between sexes, reference values can be provided which in turn can be used in injury prevention protocols.

2.3.3 Neck Morphology and Functionality

Neck Morphology

According to evolutionary principles, the mammalian neck adopts a variety of postures during daily life which differentiate and generate numerous head trajectories (Arnold, 2020). The exceedingly low level of interspecific variation in the number of cervical vertebrae of mammals has puzzled biologists for two centuries, with all mammals having seven cervical vertebrae with the exception of tree sloths (Galis 1999; Narita and Kuratani 2005; Buchholtz et al. 2012). On the contrary, functional, and morphological diversity within mammalian species is highly modular, meaning that certain traits may evolve independently of others. These interspecies differences are often pronounced, as noted by Arnold, (2020) and may also be observed within the human population. Sex differences were identified in cervical spine biomechanics, with females specifically having increased rates of trauma-related neck pain (Cassidy et al., 2000), whilst demonstrating greater physiologic (Lind, Sihlbom, Nordwall, & Malchau, 1989) and dynamic (Stemper, Yoganandan, & Pintar, 2004) spinal motions. Stemper et al. (2008) conducted a study to investigate anatomical sex differences in cervical vertebrae. The study found that, with size-matched volunteers (matched in both height and head-circumference dimensions), male vertebrae were significantly wider, while disc-facet depths were significantly longer compared to female counterparts. These findings were in accordance with previous studies who did not use sized-matched populations (Francis, 1955; Hukuda & Kojima, 2002; Katz, Reynolds, Foust, & Baum, 1975).

Neck Stabilisation Techniques: Dynamic

Dynamic joint stabilisation is defined as the ability of the myo-tendon unit to absorb external loads and minimise excessive joint movement (Riemann & Lephart, 2002). Dynamic head-neck stabilisation strategies (muscle activity, reaction time, stiffness, and strength) in addition to structural morphology determine the functionality of an individual’s head-neck complex (Tierney et al., 2005). Females have a lower total body mass than males with the female head-neck complex comprising of a lower total percentage (8.20%) of their total body mass compared to males (8.26%) (Plagenhoef, Gaynor Evans, & Abdelnour, 1983). There are four components of dynamic stabilisation: muscle activity, timing, stiffness, and muscle strength (Tierney et al., 2005). There are two major dynamic stabilisers of the head-neck complex: the sternocleidomastoid (SCM) and the trapezius (Vasavada, Li, & Delp, 1998). These muscles provide stability via concentric flexion and eccentric extension (SCM), and trapezial concentric extension and eccentric flexion, respectively. Prior to the addition of an external force load, the greater magnitude of muscle activation and faster onset of activation of these stabilizers will lead to a reduced resultant head acceleration. This is due to the combined mass of the head-neck complex and the torso. (Bauer, Thomas, Cauraugh, Kaminski, & Hass, 2001; Kumar, Narayan, & Amell, 2000). The contraction of these primary stabilisers also increases muscle and joint stiffness (Wittek, Ono, Kajzer, Ortengren, & Inami, 2001) which further increases segmental resistance to motion when external forces are applied by at least ten-fold (Reid, Raviv & Reid Jr, 1981).

Cervical muscle strength is another key component for dynamic stabilisation. Insufficient muscle strength predisposes individuals to increased injury risks of injuries such as concussion. This is a result of a reduced magnitude of resistance to counter any external forces involved in head acceleration (Hrysomallis, 2016; Naish, Burnett, Burrows, Andrews, & Appleby, 2013). In an aged-matched population, Garces, Medina, Milutinovic, Garavote, & Guerado, (2002) reported that male participants produced 30-40% greater isometric cervical flexor and extensor strength than females, with the results being attributed to increased muscle mass. The ability to effectively stabilise the head and neck complex under external loading conditions has been shown to reduce the risk of head-neck complex injuries. Females typically exhibit lower cervical strength compared with males, which may increase their susceptibility to injury under comparable external loading conditions.

Neck Stabilisation Techniques: Static

Another form of stabilisation of the neck is that of static stabilisation. The term 'static stabilisation of the neck' refers to the cervical spine's innate anatomical features that promote the stability of the cervical column (Stemper et al., 2008), which as previously mentioned are greater in males. However, it has been reported that males may in-fact have lower static stability due to a larger head circumference and C1-C5 length. These differences in column length and cross-sectional area were reported instead to have an impact on bending resistance, with longer and thinner columns being more prone to bending and greater segmental motion. Therefore, cross-sectional spinal geometry is thought to play a key role in spinal stability and may explain why female injuries are more common.

2.4 Current Functional Implications of Dimorphic Differences

2.4.1 Real World Practical Implications

Implications of Dimorphic Spinal Morphology in Society

As a society, gender disparity in all levels of society unfortunately remains. Many industries, however, have developed to provide increased female participation and involvement. The automotive industry has seen a rise in female participation that has become equally as prominent as male participation. The stark realisation however is that the rises in female participation are subdued by a societal complacency in relation to injury prevention and car safety. Clinical and epidemiological studies investigating the statistics of individuals who received whiplash injuries during automotive collisions found that 57% of whiplash sufferers were female (Mayou & Bryant, 1996). Jönsson, Tingvall, Krafft, & Björnstig, (2013) investigated a Swedish insurance company's (Folksam) whiplash data between 1990-1999 that had resulted in at least one permeant neck injury caused by rear-end impacts. A total of 430 impacts which included 860 occupants and 444 impairments were reviewed. It was found that females accounted for 302 of the impairments with male impairment being 142, making the relative risk of medical impairment being 2.1 times greater for females.

Whiplash biomechanics in the 1990s drew much attention due to the increased advancement in technology; in particular, high-resolution imaging techniques that were necessary to record rear impact events (Luan et al., 2000; McConnell et al., 1995). Investigations into insurance claim statistics found that females reported 61% of all whiplash claims in the six-months before and 12-months after a change from a tort-compensation insurance system to a no-fault system in Saskatchewan, Canada (Cassidy et al., 2000). These developments in turn shaped the need for an explanation into the possibilities of why females were receiving higher rates of whiplash.

Initial studies were contradictory; Lind, Sihlbom, Nordwall, & Malchau, (1989) used a combination of radiology and clinical examination in 35 males and 35 females and found no significant difference in the flexion-extension range of the neck (whilst females were found to be higher 76 degrees vs 68 degrees). Youdas et al., (1992) found significantly greater ranges of extension in females. A pivotal publication arose through Van Den Kroonenberg et al., (1998), who tested 19 human volunteers at certain velocities whilst strapped to a standard car seat mount. The results showed that females sustained greater peak head accelerations compared to their male counterparts, however, these data were limited as only included three female subjects.

In 2004, Stemper, Yoganandan, & Pintar built on their previous research on static stabilisation. They investigated localised facet joint kinematics during the result of simulated whiplash acceleration. The kinematics were measured in the dynamic domain during the time of cervical S-curvature (lordosis) using both intact head and neck specimens from cadavers alongside a pendulum mini-sled loading apparatus. The investigation of these factors was to determine the effects of sex, impact severity, cervical level and anatomic joint regions on shear and distraction motion of the lower cervical facet joints. From a structural perspective, the results presented variations in neck-circumference (females having smaller neck circumference) which in turn led to increased segmental kinematics in both the shear and axial motion. In lay language: Females have an increased susceptibility to buckling of the cervical spine. This explained one factor that increased the risk of sustaining whiplash in females. This paper provides an accurate representation of real-time kinematics in both the male and female sex. Another reason for its success is due to the use of human cadavers. Cadavers allowed for temporal motion of the skull to be recorded, which is important to help determine accurate lifelike whiplash kinematics, without inducing any physical harm to live participants.

In 2008, Stemper et al., (2008) developed their research further by examining differences in the anatomical structure of the cervical spine vertebrae with both the sex and spinal level as variables. This time they reported that sized matched volunteers that were both male and female saw that females had smaller dimensions for six of the seven metrics measured. In turn seeing that females had more unstable cervical spinal columns which are not as resilient at resisting the inertial loading of the head-neck complex during rear-automotive impacts. Prior to 2008, Gilsanz et al., (1994) suggested that differences in vertebral mass between males and females was accounted by the fact that cancellous bone density differed between sex. After investigation, the differences in vertebral mass were due to the differences in dimensions of the vertebrae. With vertebral masses being found to be larger in males than in females, even if they were matched for age height and weight.

2.4.2 Current Dimorphic Implications in Sporting Injury Risk

Anterior Cruciate Ligament Injuries in Females

Studies have highlighted that the risk of anterior cruciate ligament (ACL) tears is greater in females during the same landing and cutting sports with the incidence of female to male is 3.5 times greater in basketball and 2.8 times greater in soccer (Ireland, 2002). Such elevated risks along with the increase in female sporting participation have seen a rapid rise in the documentation of female ACL injuries (Ireland, 2002). Hewett, Myer, & Ford, (2006) acknowledged the importance of understanding the underlying mechanisms that directed the gender disparity in ACL injuries, by discussing both the extrinsic and intrinsic risk factors associated with the injury mechanism. Of the anatomical (intrinsic) hypothesis, several studies of the ACL focused on measures such as tibia length, thigh-length, and height (Fleming et al., 2001).

Whilst different bone lengths may increase the risk of ACL injuries; anatomical measures often do not correlate with dynamic injury mechanisms (Hewett et al., 2005). However, another anatomical hypothesis reported a relation to the Q-angle of the hip (Haycock, 1976; Zelisko, Noble, & Porter, 1982). Larger quadriceps angle (Q-angle) (Horton & Hall, 1989; Woodland & Francis, 1992) are thought to contribute to excessive amounts of knee valgus (lateral angulation or abduction of the tibia with respect to the femur). The combination of knee valgus and external rotation positions contribute to ACL impingement and injury (Fung & Zhang, 2003; Lephart, Abt, & Ferris, 2002). Yu, Lowe, Griffin, & Dong, (2020) alongside a Japanese study by Mitani, (2017) disputed the advance of large Q-angles as the reason for increased risk. Mitani, (2017) examined the Q-angle of 224 participants, both female and male athletes. No statistical associations between Q-angle and ACL tears in female athletes were reported. Instead, a significantly higher angle of internal rotation of the hip joint was noted in females compared to males. The position of internal rotation of the hip joint is thought to determine the increased risk for ACL injury. This biomechanical function, rather than an increased Q-angle, was associated with increased ACL tears in these female athletes.

The divergence in the hormonal environment between females and males during puberty was reported to affect injury risk and motor control patterns by Sigward, Pollard, Havens, & Powers, (2012). Subsequent studies have provided further evidence of the role of sex hormones in ACL injury risk, including the presence of hormone receptors in the ACL (Dehghan et al., 2013; Liu et al., 1996). A higher occurrence of ACL injuries has also been reported during the follicular and preovulatory phases of the menstrual cycle (Arendt, Bershadsky, & Agel, 2002; Slauterbeck et al., 2002). The combined effects of oestrogen and relaxin are believed to influence collagen turnover and cross-linking, resulting in increased laxity in ligaments, decreased ACL load-to-failure, and reduced tendon stiffness (Dehghan et al., 2013; Dragoo, Padrez, Workman, & Lindsey, 2009; Yu, Panossian, Hatch, Liu, & Finerman, 2001). A prospective study on collegiate athletes found that a relaxin concentration of ≥6.0 pg/mL was associated with a four-fold increase in ACL tears (Dragoo et al., 2011).

While the specific impact of sex hormones on ACL injury risk in men is not well understood, testosterone has been shown to stimulate collagen fibroblast production and potentially contribute to ACL strength (Lovering & Romani, 2005). Genetic variants related to collagen formation, such as COL1A1, have been linked to ACL injury but this association appears to be specific to females (Posthumus et al., 2009).

Bone Density and Female Injury Risk

Sex-related prevalence rates of osteoporotic fractures have been reported, with males exhibiting more favourable characteristics in bone mineral density, geometry, and strength (Nieves, 2017). These differences can be attributed to factors such as body size, composition, hormones, and the bone's response to mechanical loading.

Sex-specific bone adaptations to mechanical loading are influenced by sex steroid receptor signalling and can affect the bone's response to loading (Almeida et al., 2017; Saxon et al., 2012). The female skeleton is reported to be less responsive to mechanical loading, which inherently increases the risk of mechanical fractures in females (Baker et al., 2020). This is evident in studies investigating stress fracture incidence rates during military training, where stress fractures were found to be more prevalent in females compared to males (Brudvig et al., 1983; Pester & Smith, 1992).

Smaller bone sizes in women contribute to their increased susceptibility to stress fractures when the same load is applied to male bones (Tommasini et al., 2007). Disruptions to hormonal mechanisms, such as delayed menarche and oestrogen deficiency due to intense exercise, have been associated with reduced peak bone mass in female athletes (Maïmoun et al., 2014). This reduction in bone mass can lead to a higher risk of severe osteoporosis later in life for physically active females compared to sedentary adolescents (Maïmoun et al., 2014).

2.4.3 Unexplored Dimorphic Implications on Female Injury Risk

Hand Span and Skill Scaling

Not only does the literature provide evidence for morphological and functional implications on injury risk, but there are also other aspects of the women's game that may have increased injury risk complications that are currently unexplored. In the present day, both adult males and females compete with a size five rugby ball, despite females being found to have a hand span that is 11% smaller than males (Ruiz et al., 2006). Not only were sex differences found in anthropometric measurements, but differences were also explored in functional aspects. Ruiz et al., (2006) reported that in determining maximum handgrip strength, hand span is a major influence on female grip strength. Male grip strength on the other hand was not hand span dependent.

Whilst females are found to have a hand span 11% smaller than their male counterparts, females are still instructed to use a size five rugby ball. The dimensions of a size five rugby ball as stated by World Rugby are 280-300mm in length, 580-620mm in circumference and 185-197mm in diameter. With the average male hand span being 21.0cm and the female hand span being 18.7cm (Ruiz et al., 2006), the average male can grip ~70% of the total circumference of the ball with both hands. Whereas the average female can grip ~62% of the total circumference. Whilst this difference may be ~8% on average, the total percentage can vary significantly depending on the individuals hand span. The effects on skill acquisition and incorrectly scaled equipment size have been shown in vast literature to be dramatic.

The value of scaling sport for children is very evident. For example, envision a seven year-old child playing rugby with the same sized equipment used for participating adults. In these circumstances, children will experience a high degree of difficulty in trying to complete the task successfully. Skill acquisition is a process of self-organisation that is dependent upon the demands and constraints imposed on the system under focus (Davids, Button, & Bennett, 2008; Newell, Van Emmerik, & McDonald, 1989; Renden & Dikken, 2023). The demands may be either internal or external that help defines the boundaries within which the human neuro-musculoskeletal system must operate.

Newell, Van Emmerik, & McDonald, 1989 explicitly divided the constraints into 3 categories: Task-related – The rules and goals of the defined task along with the equipment used, Organismic – The individual's physical and psychological characteristics and finally Environmental – The external forces surrounding the performer. Therefore, optimal movement patterns are suggested to be developed from a combination of the 3 types of constraints. Concerning the type of equipment used i.e., the task constraint, it allows children who potentially lack the strength, fitness and or coordination to successfully use adult equipment sufficiently, the opportunity to perform and develop skills to create the optimal movement patterns for game tasks. By doing this, children can create perception-action processes that are considered vital for coordinated movement patterns (Davids, Button, & Bennett, 2008). Therefore, if female adults are having to develop and master optimal movement patterns with suboptimal task constraints, this may in turn result in altered movement patterns to produce 'optimal' movement patterns which stretch the boundaries in which the neuro-muscular system can operate and therefore increase the risk of injuries occurring.

Implication of Breasts on Female Injury Risk

One glaring difference between males and females is the difference in chest mass i.e., breast tissue. Female athletes who participate in contact sports are at a greater risk of experiencing acute contact injuries. Brisbine, Steele, Phillips, & McGhee, (2019) recently reported that from 297 female athletes from across Australian Football, Rugby League, Union, and 7s, 58% experienced breast contact injuries. It was further reported that ~50% of those who reported a breast injury said their injury negatively affected their sporting performance. One strategy that is used already is the use of padding, this technique can increase the surface area over which contact forces are spread, to minimise the frequency of soft-tissue injuries (Gerrard, 1998). Independently of padding, many female athletes report that they wear a sports bra to support their breasts whilst they train and compete (Comstock, Fields, & Knox, 2005). Sports bras that are properly fitted and well-designed have been shown to reduce the amount of breast motion experienced which is more of an issue for females with larger breasts (McGhee, Steele, Zealey, & Takacs, 2013).

Excessive trunk rotation, extension and flexion have been reported to decrease running economy (Messier & Cirillo, 1989), with lower vertical displacement of the trunk being linked to a greater running economy (White, Mills, Ball, & Scurr, 2015; (Hinrichs, Cavanagh, & Williams, 1987). The effect of breast support on arm swing mechanics and therefore as an indirect influence ball-carrying technique in rugby has remained unclear. In 2009, White, Scurr, & Smith, (2009) provided a preliminary investigation in arm range of motions between different breast support conditions with runners of a B or C cup in particular; with no differences in arm angle ROM being found. In a more recent study Scurr, White, & Hedger, (2011) suggested based on subjective feedback from their study that females with larger breast sizes have increased pain when performing running activities. This in turn may lead to females reducing torso rotation and compensating with either a great arm swing or a crossover method to help support and reduce side-side motion of the body (Arellano & Kram, 2014).

As with the scaling technique, if females are struggling to recreate and develop optimum skill and movement patterns due to either physical or task constraints, this, in turn, will result in the exploration into alterations of optimal movement patterns, in the case of breasts, changes to upper extremity movement patterns which in turn may A. Increase the risk of injuries occurring due to suboptimal movement patterns or B. Increase the risk of injuries through manipulation of the body structure to produce these alternative movement patterns.

Shoe Fit and Foot Morphology on Female Injury Risk

Vast quantitative data exists on how the shape of an individual's foot shape is essential to achieve comfortable shoe designs. Studies imply that to obtain the correct shoe fit, the shoe must align with the shape of the foot (Wunderlich & Cavanagh, 2001). The structural and biomechanical functions of both the ankle and foot differ between the sexes. This should be an important consideration for injury risk management as a major extrinsic factor that causes foot deformities and pain in females is the shoe (Frey, 2000; O'Connor, Bragdon, & Baumhauer, 2006). Despite this, it has been established that female's sports shoes were designed as smaller versions of the male designs, with the shoe dimensions being proportionally scaled to the length of the individual's foot (Krauss, Valiant, Horstmann, & Grau, 2010). As there are defined sex differences in structure and function of the ankle and foot, shoes that are made without considering these constraints lead to an improper fit for females and therefore can increase injury risk in both static and dynamic situations (Wunderlich & Cavanagh, 2001). In relation to differences in foot dimensions Frey, (2000) reported that females tend to have a narrower heel in relation to their forefoot, and their instep height was lower than their male counterparts when the study population have the same foot length (Krauss, Grau, Mauch, Maiwald, & Horstmann, 2008) and finally females have increased ankle girth, lower first toe height, malleolus height, instep girth and lateral / medial ball length in a population with the same foot length (Wunderlich & Cavanagh, 2001). By providing females with ill-fitting equipment, there is a potential for increased risk of injury occurring under dynamic situations.

2.4.4 Coaching, Equipment, and Societal Attitudes and Their Influence on Injury Risk

Effects of Coaching Expertise on Injury Risk for Female Athletes

Coaching expertise plays a crucial role in shaping the overall well-being and injury risk of female athletes. Research has shown that the coaching style and behaviour of sports coaches can significantly influence the motivation, performance, and injury risk of athletes (Deci & Ryan, 2000). Specifically, autonomy-supportive coaching, which emphasises the athlete's goals and needs while providing a supportive and nurturing environment, has been found to positively impact communication and athlete development (Amorose & Anderson-Butcher, 2007; Bartholomew, Ntoumanis, Ryan, & Thøgersen-Ntoumani, 2011). This coaching approach fosters a positive coach-athlete relationship, leading to effective communication and a supportive environment, which in turn can contribute to the reduction of injury risk. Moreover, the level of experience and expertise of the coach has been identified as a critical factor in injury prevention and management. Coaches with a higher level of expertise are more likely to have the knowledge and skills to design appropriate training programs, identify potential injury risks, and provide effective injury prevention strategies (Soligard et al., 2015). Therefore, the coaching expertise and behaviour of sports coaches are direct influencers of injury risk for female athletes, as they can influence the athletes' motivation, performance, and overall physical well-being.

Levels and Availability of Sporting Equipment

The availability and proper use of sporting equipment are essential in mitigating the risk of sports injuries among female athletes. Research has highlighted the importance of wearing appropriate and well-fitted sports equipment to reduce the likelihood of sustaining injuries (LaBotz et al., 2016). The quality and accessibility of sports equipment, such as protective gear, footwear, and training apparatus, are crucial factors in injury prevention and risk reduction (Ekegren, Donaldson, Gabbe, & Finch, 2014). Ensuring that female athletes have access to and utilise proper sporting equipment is essential in minimising the risk of sports-related injuries. Furthermore, the maintenance and inspection of sports equipment, including regular checks for wear and tear, proper fit, and functionality, are integral components of injury prevention strategies (Kerr, Hayden, Dompier, & Cohen, 2015). Inadequate or faulty sports equipment has been identified as a significant risk factor for sports-related injuries, underscoring the critical role of proper equipment in reducing injury rates among female athletes (Ekegren, Donaldson, Gabbe, & Finch, 2014). Therefore, the availability, quality, and proper use of sporting equipment are fundamental considerations in addressing and managing the injury risk for female athletes.

Social Attitudes and Injury Risk for Female Athletes

Social attitudes and perceptions regarding female athletes can influence their overall well-being and injury risk. Research has shown that negative social attitudes and gender biases towards female athletes can impact their experiences in sports and physical activities, potentially increasing their susceptibility to injuries (Fink, 2015). Addressing and challenging these biases are essential steps in creating an inclusive and supportive environment for female athletes, which can contribute to the reduction of injury risk. Moreover, promoting positive social attitudes and equitable treatment of female athletes can have a profound impact on their participation, performance, and overall physical health (Fink, 2015). Enhancing awareness, education, and advocacy efforts aimed at challenging gender stereotypes and biases in sports and physical activities can contribute to creating a more supportive and inclusive environment for female athletes, reducing their vulnerability to sports-related injuries. Therefore, social attitudes and perceptions play a pivotal role in shaping the experiences and injury risk of female athletes, highlighting the need for concerted efforts to address and transform negative attitudes and biases within the sporting community.

By highlighting the vast areas that influence injury risk, it is evident that injury prevention strategies that take physical and psycho-social considerations related to females into account is still limited. It is also evident that there is still a large gap in sex-based research which may negatively impact the risk of females when partaking in sport. The purpose of this study is to gather a large pool of data from female rugby union players across various levels of competition about their previous injury history. To then highlight any trends or areas of concern and begin to explore the potential reasons behind this, which in turn can direct future areas of research.

Chapter 3 Methods

3.1 Survey Background

3.1.1 Survey Development and Rationale

Due to the limited data currently available regarding injury epidemiology in female rugby players, this thesis aimed to assess the understanding, experiences, and attitudes of players and in women's rugby union regarding key topics. Specifically, these topics included concussion, injury type and prevalence and training for injury prevention. Furthermore, the implications of the menstrual cycle on training and performance were explored.

An open, cross-sectional global survey for women rugby union players, set up for web-based data entry, was developed by a collaborative research group. Survey responses were recorded anonymously via the GDPR-compliant online survey platform JISC (jisc.ac.uk, Bristol, England). To enable global distribution and accurately represent the responses, the survey was professionally translated into eight languages: French, Spanish, German, Italian, Japanese, Welsh, Cantonese and Russian, with English being the original language of the survey. For survey responses completed in non-English languages, all written answers were professionally translated into English to maintain response accuracy.

Internet-based surveys may be prone to significant bias, which can impact the validity of the survey results. In this case, the volunteer effect resulting from the self-selection of participants may have led to an unrepresentative global sample of women rugby players (Eysenbach, 2004). Players in regions with limited internet access may have been underrepresented. Therefore, the methods used align with the Checklist for Reporting Results from Internet E-Surveys (CHERRIES) (Eysenbach, 2004). This aims to provide readers with more information on sample selection and its representativeness of the target population.

In August 2020, the surveys were initiated and kept open for a duration of 12 weeks, until November 2020. Although the data was collected during the COVID pandemic, the questions were framed to reflect on 'normal activities' based on the state responses. To gather responses, both snowball and purposeful sampling methods were employed

(Gelinas et al., 2017). The promotion of the surveys was done through a promotional e-poster that contained links to the survey in the nine different languages. This e-poster was shared on women's rugby social media platforms and news websites. Additionally, contact was established with potential participants by reaching out to mailing lists from world and national rugby governing bodies. A participant information sheet was presented on the first page of the survey, followed by a consent form, which participants were required to accept to open the survey. Due to the anonymous nature of the survey, all data were confidential; participants were informed that they would not be able to withdraw their responses once submitted as a result. Moreover, due to the anonymity of the survey, specific identification of and intervention for participants with medical risk factors were not feasible. For the players' surveys, inclusion criteria were being ≥18 years and regular players, respectively, of women's rugby (rugby 15s and sevens) at any level, for any rugby club or organisation, in any country, in the past ten years. Voluntary participation in this study was not incentivised. Participants were informed that by completing the survey, they would be making an invaluable contribution to the knowledge base of women's rugby. Specifically, the information would be used with the aim of improving training strategies, practices, and guidelines specifically for women athletes. Items were presented to each participant in the same order; as this was an individual survey, completed independently, the order that questions were presented was not considered to introduce any potential bias.

3.1.2 Survey Authorship and Dissemination

The full survey included a maximum of 149 multiple choice questions, presented across three sections.

Section One: Demographics, Playing Positions, Experience, and Health Information. This section gathers basic information about the participants, including demographics such as age, ethnicity, and nationality. It also collects data on the players' positions in rugby, their experience level, and information about their overall health. The number of questions in this section can vary based on the previous answers provided by the participants.

Section Two: Health Monitoring, Collision Preparedness, Concussion History, Training, and Injury Management. This section focuses on various aspects of player health and well-being. It covers topics such as the players' health-monitoring practices, including regular check-ups and assessments. It addresses the players' preparedness for rugby collisions, which may involve questions about strength and conditioning programs. It also includes questions related to the players' concussion history, including any previous incidents and their management. Training practices for injury prevention and injury management are also covered in this section. The number of questions in this section can vary based on the participants' responses.

Section Three: Women-Specific Issues in Rugby. This section is specifically tailored to address women's experiences in rugby. It includes questions about concussion symptoms that are specific to women. The effects of the menstrual cycle on training, performance, and injuries are explored in this section. Topics related to female physiology, such as hormonal fluctuations and their potential impact on the players, are covered. The availability of medical support and financial resources for women in rugby is also addressed. The number of questions in this section can vary based on the participants' assigned sex at birth and their previous answers. The completion time for the entire survey is estimated to be up to 60 minutes, depending on the level of detail provided by the participants, especially in the free-text questions. The survey is designed with logic to ensure that only relevant questions are presented based on the participants' previous responses. All questions were developed specifically to address the objectives of this study. Due to the breadth of these objectives, this precluded the use of previously validated questionnaires to avoid excessive participant burden and thus engender high attrition rates. The questionnaire was also trialled by 10 former rugby players who took between 20 mins and 60 mins to complete.

3.1.3 Ethics Approval

Ethics approval for the study was granted by the College of Engineering Research Ethics Committee at Swansea University (reference number 2020-035). A participant information sheet was presented on the first page of the survey, followed by a consent form, which participants were required to complete prior to progressing to the survey. Due to the anonymous nature of the survey, all data were confidential, and participants were informed from the outset that they would not be able to withdraw their responses once submitted. This anonymity precluded the specific identification of participants with medical risk factors. Survey inclusion criteria required participants to be over the age of 18 years and to be a regular player of women's rugby union (rugby 15s and 7s) at any level, for any rugby club or organisation, in any country, in the past ten years.

3.2 Data Processing

3.2.1 Data Cleaning and Processing Response Categorisation

All responses were downloaded in Microsoft Excel® format for analysis. Of the 149 survey questions, the responses from questions one, two, four, five, six, seven, eight, nine in section one, and question 26 in section two (see Appendix A) were collated to address the specific aims of this thesis. Questions two and eight included the categorical variables of country and playing level, respectively. For Question eight, the option to select 'other' was also available, with an option to provide a free text answer describing their playing level, team, or league they participated in if it was not on the list. If a free text answer was given, the information was used in background research, to determine the equivalent or closest category according to the listed options. In various cases, this required contact with rugby federations to directly assess their level, or to investigate the level of the league that their team participated in. This was based on the world ranking of their country, the number of national team players in the league, and the overall number of players in the league. In these situations, players were then categorised appropriately based on their highest reported playing level. Questions 3,4,5,6, and 7 were continuous variables: age (years), height (cm), body mass (kg), age of first rugby participation (years) and playing experience (years), respectively.

3.2.2 Data Analysis

Responses to Section 2, Question 26, "During your rugby career, please list the injuries you have sustained and the number of times you have suffered each injury" were then analysed. All reported injuries were cross-checked with the Orchard Sports Injury and Illness Classification System (OSICS) (Rae & Orchard, 2007) for a medical definition. Strict exclusion criteria were implemented to remove ineligible responses, with responses eliminated if:

- The description of the injury lacked a defined location of on the body it occurred (e.g., a sprain).
- The description lacked a frequency or used an ill-defined frequency (e.g., many, lots, loads).
- There was no response (n = 58)
- Any reported injury that was not included on the OSIICS was excluded.

Responses to section 2, question 26 that met the following inclusion criteria were included in the analysis:

- Responses that reported that no injuries had occurred.
- Location-specific injuries (e.g., concussion) were included.
- Any response that used a singular adjective or pronoun or provided a frequency response (e.g., Concussion * 2).

Those responses that met the inclusion criteria were then subsequently divided into the following categories:

- Full eligibility: This consisted of no data being excluded from an individual's response
- Partial eligibility: An individual's response may have certain parts excluded due to it not meeting the criterion, however other parts of the response were included
- No eligibility: An individual's responses met none of the criterion and therefore the entire response was not included

3.2.3 Injury Classification

Alongside the eligibility criteria, any eligible or partially eligible responses were analysed and categorised in the injury classification database. Initially, the database comprised of common rugby injuries (e.g., Concussion, shoulder dislocation) which were cross checked with the Orchard Sports Injury and Illness Classification System (OSICS) (Rae & Orchard, 2007) prior to analysis. As individual responses were analysed, any new reported injury was also cross checked with the OSICS system and, if eligible, was added to the classification database. Alongside this, different word syntaxes were considered when determining classification (e.g., Sprained Ankle vs

Ankle Sprain). Individual classifications (e.g., Concussion, Ankle sprain) were categorised by body region (e.g., facial, neck, shoulder, knee) and by the type of injury (e.g., Bone, muscle, tendon, ligament). Due to the large variety of categories, it was found to be appropriate that classification by location was then grouped more broadly based upon gross body regions (Upper limbs, Lower Limbs, Facial head & Neck). Therefore, injuries were assigned into the final categories illustrated in (Figure 1). To account for the variation in playing experience, the total injury count for each participant was divided by their reported number of years of rugby experience to produce a standardised injury frequency (injuries per year).

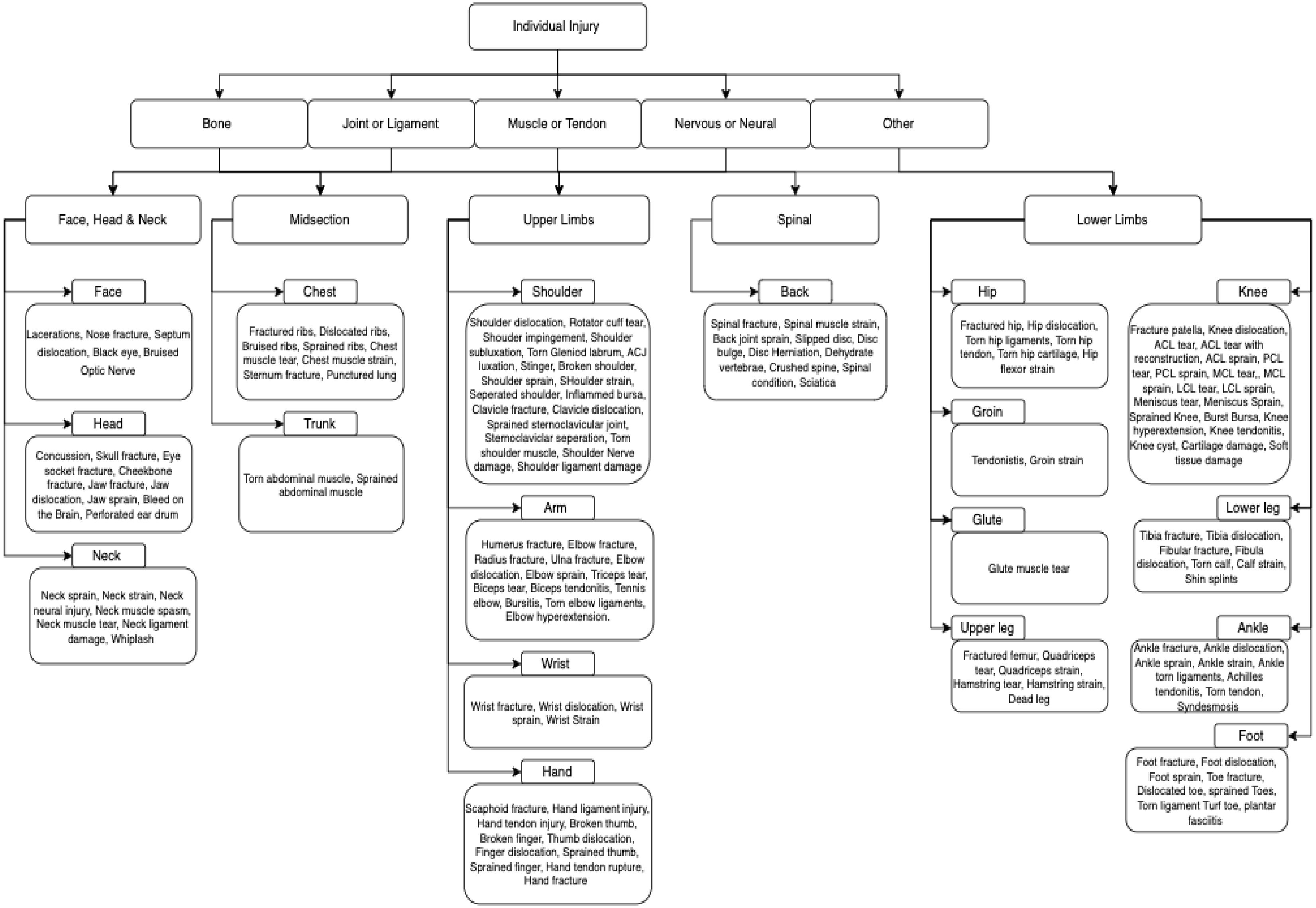

Figure 1 Flow chart showing the process by which injuries were classified based on the type and location.

3.3 Statistical Analysis

The overall survey study design was an observational, cross-sectional survey. The primary aim was to improve the knowledge and understanding of the demographic, injury and training practices of a global sample of women rugby players. For this thesis specifically, there were hypotheses regarding the secondary aim of the study that required statistical analysis. Key predictor variables of the study were height, body mass, starting age (age of first rugby participation), experience (years of rugby participation), and playing level (highest stated level). Statistical Analysis was performed using R studio (*RStudio Team (2020). Rstudio: Integrated Development for R. Rstudio, PBC, Boston, MA*), with significance set at $p \leq 0.05$.

To assess the relationship between each individual predictor variable (excluding playing level) and injury incidence, multiple regression models were employed. To assess the association between playing level and injury incidence one-way analysis of variance (ANOVA) tests were employed. Any significant results produced during the one-way ANOVAs underwent a post hoc test through the form of a Tukey HSD. This was to understand which individual playing levels produced these significant between-level differences.

To assess the relationship between each individual predictor variable (excluding playing level) and the type of injury incidence (Bone, Joint and Ligament, Muscle and Tendon, Nervous and Neural, and Other), multiple regression models were employed. To assess the association between playing level and type of injury incidence one-way analysis of variance (ANOVA) tests were employed. Any significant results produced during the one-way ANOVAs underwent a post hoc test through the form of a Tukey HSD. This was to understand which individual playing levels produced these significant between-level differences. To control for the differences in the population of different playing levels, Analysis of covariance tests (ANCOVA) were performed to further assess the association of playing level.

To assess the relationship between each individual predictor variable (excluding playing level) and the location of injury incidence (Facial, Head and Neck; Upper Extremity; Midsection; Spinal; Lower Extremity), multiple regression models were employed. To assess the association between playing level and type of injury incidence one-way analysis of variance (ANOVA) tests were employed. Any significant results produced during the one-way ANOVAs underwent a post hoc test through the form of a Tukey HSD. This was to understand which individual playing levels produced these significant between-level differences. To control for the differences in the population of different playing levels, Analysis of covariance tests (ANCOVA) were performed to further assess the association of playing level.

Chapter 4 Results

4.1 Participant Demographics

A total of 1,594 participants from 62 countries completed the survey overall (age 27± 6 years; height 1.66 ± 0.07 m; body mass 74 ± 15 kg). Of these responses, 1,465 met the inclusion criteria for this thesis. A complete response set was provided by 864 (54.2%) individuals, a partial set of responses by 601 (37.7%), and 129 (8.10%) were excluded from this study (Chapter 3.3.2). Eligible participants were then categorized into playing level groups based on their highest level of play. A summary of the playing level and geographic region is provided in Table 1. Participants were then grouped by playing position, as either forwards, backs, or both. Each eligible injury was tabulated and included in the analysis.

Table 1- A summary of participant playing level and geographic region. From left to right, playing levels are national team (Nat. Team), premier club (Prem Club), first division club (1st Div Club), first division university (1st Div Uni), second division university (2nd Div Uni) and recreational (Rec).

Region	***Total***	***Nat. Team***	***Prem Club***	***1st Div. Club***	***1st Div. Uni***	***2nd Div. Club***	***2nd Div. Uni***	***Rec.***
Europe	534	40	19	204	14	27	18	151
UK	424	120	95	82	14	83	6	6
Asia	98	3	1	42	2	23	1	10
South America	67	0	2	42	1	0	2	25
North America	249	114	32	14	37	48	2	0
Africa	30	6	8	3	2	9	0	1
Middle East	9	0	1	1	1	5	0	0
Oceania	165	16	18	45	7	49	6	0
Not stated	18	9	1	3	4	0	0	0
Total	**1594**	**308**	**177**	**436**	**82**	**234**	**35**	**193**

4.2 Playing Level, Anthropometrics, and Injury Patterns

Table 2 provides a summary of the height, body mass, starting age, and experience across the levels of competition. Whilst no significant differences were highlighted for all playing positions combined between competition levels for their height, starting age, or experience, players were found to have significantly different body mass across the levels of competition. Post-hoc investigation into the intra-level differences in competition failed to identify any specific differences between the individual levels, only across all levels.

Table 2 - Population demographics for all countries combined.

	International	Premier Club	Club 1st Division	University 1st Division	Club 2nd Division	University 2nd Division	Recreational	p value
Individuals (n)	308	177	436	82	234	35	193	
Height (cm)	167.2 ± 6.5[1]	167.3 ± 7.8	166.8 ± 7.1	167.8 ± 7.1	167.6 ± 7.5	165.3 ± 8.5	165.7 ± 7.7	0.076
Body Mass (kg)	76.8 ± 16.3	75.5 ± 15.5	73.9 ± 15.8	79.7 ± 16.9	75.0 ± 14.2	74.4 ± 18.1	68.5 ± 12.9	< 0.01*[2]
Age (Years)	18.3 ± 6.2	19.4 ± 6.9	18.1 ± 6.6	18.9 ± 5.7	17.5 ± 6.0	18.5 ± 6.2	18.3 ± 6.0	0.31
Experience (Years)	7.6 ± 5.0	7.3 ± 5.6	6.9 ± 4.9	9.4 ± 5.5	8.4 ± 5.4	8.3 ± 4.0	7.5 ± 4.7	0.166

Table 3 - Most frequently reported injuries (the number of individuals reporting the injury, the overall frequency of each injury, and the average number of occurrences amongst those reporting the injury).

	Individuals Reporting the Injury		Frequency		Average Number of Occurrences
Injury	(n)	(%)	(n)	(%)	(n)
Sprained Ankle	624	42.59	1656	24.25	2.65
Concussion	348	23.75	825	12.08	2.37
Finger Fracture	200	13.65	397	5.81	1.99
Nose Fracture	163	11.13	253	3.71	1.55
Torn ACL	158	10.78	191	2.8	1.21

[1] The mean value is reported with ± standard deviation.
[2] A significant difference indicator.

4.3 Overall Injury Demographics

In this analysis, 6,829 injuries were reported and classified into 147 different types (Figure 1). The top five most frequently reported injuries accounted for 48.7% of the total injury incidents, while the other 142 types made up the remaining 51.3% (Table 3). The most reported injury was sprained ankles, which also had the highest rate of recurrence.

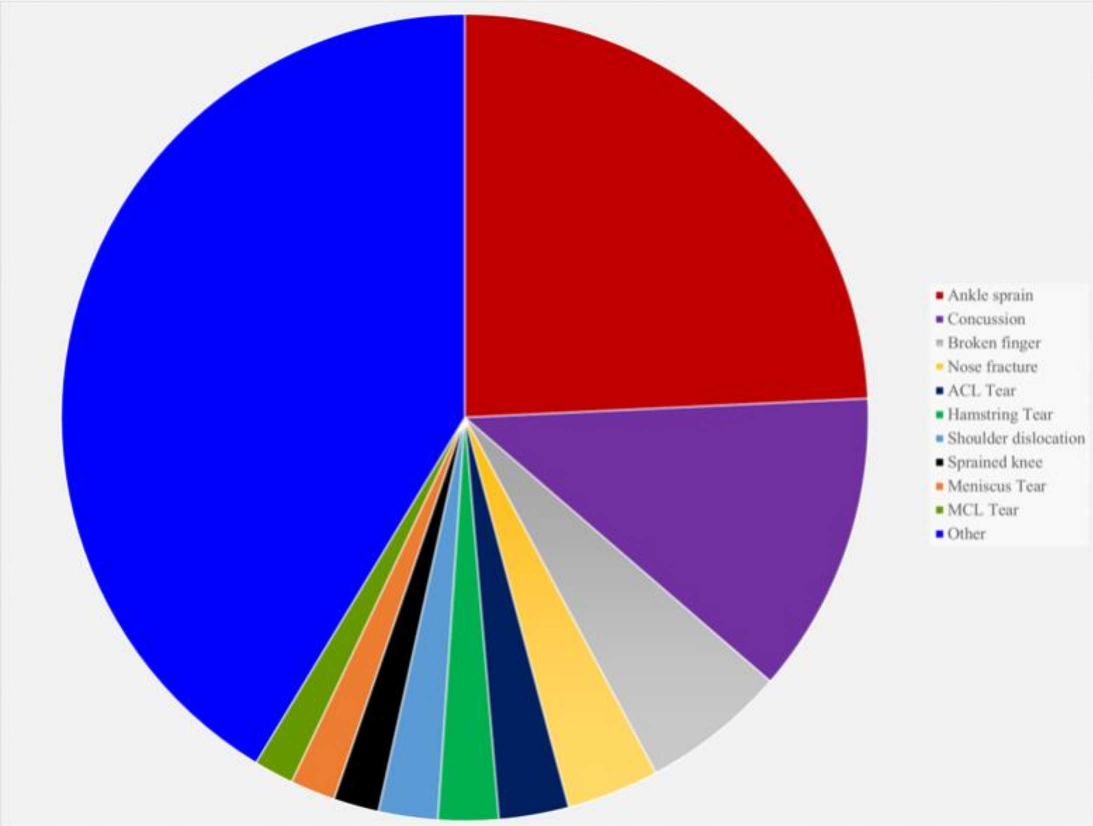

Figure 2 Injury incidence for the top 10 highest incidences, with "Other" representing the remaining 137 injury types.

4.4 Playing Level vs Injury Epidemiology

Across the various levels of competition, various injury rates were reported with individual's reporting an average of 4.66 injuries per year. Amongst the individual playing levels, the highest average injury incidence was reported in university 1st division players, with the lowest being found in university 2nd division players (Table 4). Significant differences injury incidence was found across all playing levels (p = < 0.001). Post-hoc testing revealed athletes classified as international saw significantly different overall incidence rates to university 2nd Division (p = 0.02) and Recreational athletes ($p = < 0.001$). Premier athletes reported significantly different injury incidence rates to university 2nd Division ($p = 0.006$) and Recreational athletes ($p = < 0.001$). With 1st and 2nd division clubs seeing significant differences with recreational athletes (1st Div $p = 0.047$) (2nd Div $p = 0.036$).

Table 4 - Self-reported injury rates for each playing level.

Playing Level	*Total Injury Count*	*Average Injury Count per Individual*
International	1,702	5.53
Premier Club	916	5.18
Club 1st Division	1,776	4.07
University 1st Division	481	5.87
Club 2nd Division	1,250	5.34
University 2nd Division	104	2.97
Recreational	600	3.11

Across the playing levels, there was variation in the top five most reported injuries. However, except for those classified as university 2nd division athletes, all the other playing levels had the same two most reported injuries, namely ankle sprain and concussion. The next three most reported injuries ranged from: Nose fractures, ACL tears, fractured fingers, knee dislocations, hamstring tears, shoulder dislocations, and sprained fingers (Table 5).

4.5 Predictor Variables vs Injury Type and Incidence

Table 6 provides an overview for the relationship between each predictor variable and their influence on the type of injury that are reported. It was reported that significant differences were found in injury incidence when investigating the effects of height, body mass, starting age, and experience, yet not for playing position. Except for experience, all the other variables saw miniscule increases in injury incidence, as the variables increased in size. It was noted that as experience increased, injury incidence decreased. In relation to experience, it was shown that the more experience an individual had acquired, a small significant reduction in injury incidence rates were seen, except for injuries classified as 'other', which saw no significant effect on incidence rate from experience. The age at which participants began playing rugby significantly affected the incidence rates of ‘muscle or tendon’ injuries, with a greater incidence in participants with an older starting age (*p* = < 0.01). Body mass was also found to significantly affect incidence rates in ‘joint and ligament” injuries, those with greater mass incurring a higher incidence rate (*p = 0.044*).

Table 5 - The five most reported injuries for the seven different playing levels.

	Injury Type						
Injury frequency rank	***International (n)***	***Premier Club (n)***	***Club 1st Division (n)***	***University 1st Division (n)***	***Club 2nd Division (n)***	***University 2nd Division (n)***	***Recreational (n)***
1st	Ankle Sprain (403)	Ankle Sprain (154)	Ankle Sprain (459)	Ankle Sprain (116)	Ankle Sprain (357)	Concussion (18)	Ankle Sprain (150)
2nd	Concussion (216)	Concussion (119)	Concussion (184)	Concussion (94)	Concussion (154)	Ankle Sprain (17)	Concussion (40)
3rd	Finger Fracture (130)	Finger Fracture (66)	Finger Fracture (93)	Finger Fracture (41)	Nose fracture (46)	Knee dislocation (8)	Nose fracture (32)
4th	Nose fracture (75)	Shoulder Subluxation (51)	ACL Tear (63)	Nose fracture (16)	Shoulder dislocation (43)	Hamstring Tear (6)	Finger Fracture (26)
5th	Hamstring Tear (47)	Nose fracture (24)	Nose fracture (58)	ACL Tear (15)	Finger Fracture (37)	Finger Fracture (4)	Sprained Finger (24)

Table 6 - Statistical results showing the relationship between each predictor variable and the influence on injury type.

	Standing Height (cm)		***Body Mass (kg)***		***Starting Age (years)***		***Experience (years)***		***Position***			
Type of injury	***p***	**β**	***p***	**β**	***p***	**β**	***p***	**β**	***p***	**β**	**F (4,1460)**	**R^2**
All	0.095*[3]	0.006	0.012*	0.004	< 0.01*	0.013	< 0.01*	-0.055	0.836	0.007	43.24	0.126
Bone	0.059	0.002	0.617	< 0.001	0.051	0.003	< 0.01*	-0.008	0.695	0.005	9.846	0.029
Joint and Ligament	0.345	0.002	0.044*	0.002	0.068	0.004	< 0.01*	-0.026	0.856	0.004	20.29	0.062
Muscle and Tendon	0.571	< -0.001	0.051	0.001	< 0.01*	0.005	< 0.01*	-0.006	0.071	0.024	11.22	0.034
Neural and Nervous	0.221	0.001	0.466	< 0.001	0.09	-0.002	< 0.01*	-0.011	0.574	-0.007	9.030	0.027
Other	0.555	< 0.001	0.993	< 0.001	0.091	< 0.001	0.059	< 0.001	0.405	-0.010	2.491	0.005

[3] Denotes statistical significance

Playing level was found to significantly affect the incidence rates of the type of injuries occurring (Table 7). For ‘Muscle and Tendon’ injuries, a post-hoc test identified a significant difference between premier club and recreational participants (*p* = 0.029). Post-hoc testing identified differences in incidence rate for injuries classified as ‘Neural and Nervous’ between recreational participants, and those classified as national team (*p* = < 0.001), premier club (*p* = < 0.001), university 1st team (*p* = 0.014), and club 2nd division athletes (*p* = 0.034). No significant differences in the incidence of ‘Bone & Joint and Ligament’ injuries were found when employing post-hoc tests between group playing levels.

Table 7 - ANOVA (analysis of variance) results of the effects of the level of competition on the type of injuries

Type of Injury	***p***	***F (1,1463)***
Bone	< 0.01*	12.37
Joint and Ligament	< 0.01*	10.02
Muscle and Tendon	0.026*	4.996
Neural and Nervous	< 0.01*	17.48
Other	0.237	1.398

When accounting for the differences in population across each competition level (Table 8) it was reported that only two of the predictor values had significant influences on incidence rates. Starting age was found to significantly influence the incidence rates of injuries classified as ‘joint and ligament’ injuries (*p* = 0.043). Rugby experience significantly influenced the incidence rate of injuries classified as ‘nervous or neural’ (*p* = 0.005).

Table 8 - ANCOVA results depicting the effects of height, body mass, starting age, rugby experience, and competition level on the incidence rates of the types of injury, accounting for differences in population size for each different competition level

	Height		***Body Mass***		***Age***		***Experience***	
Injury type	***p***	**F (1,1461)**	***p***	**F (1,1461)**	***p***	**F (1,1461)**	***p***	**F (1,1461)**
Bone	0.292	1.11	0.721	0.127	0.779	0.079	0.832	0.045
Joint and Ligament	0.192	1.705	0.441	0.593	0.043*	4.098	0.347	0.884
Muscle and Tendon	0.528	0.399	0.069	3.324	0.423	0.642	0.45	0.572
Nervous and Neural	0.879	0.023	0.428	0.629	0.452	0.565	0.005*	7.8
Other	0.765	0.089	0.874	0.025	0.004*	8.218	0.075	3.164

4.6 Predictor Variables vs Injury Location

(**Error! Reference source not found.**) provides an overview for the relationship between each predictor variable and their influence on injury location. A significant inverse relationship was observed between rugby experience and the incidence of 'facial, head and neck' (p = < 0.01), 'upper extremity' (p = < 0.01), and 'lower extremity' injuries (p = < 0.01). Participants with a greater body mass had a significantly higher incidence of 'upper extremity' injuries (p =0.017). A later rugby starting age was found to significantly increase incidence rates for 'midsection' (p = 0.041) and 'lower extremity' injuries (p = < 0.01). No significant relationships were observed between playing position and injury location.

Playing level was found to significantly affect injury location, except for 'midsection' or 'spinal' injuries (Table 10). Post-hoc tests showed a significantly greater incidence of 'facial, head and neck' injuries in national team players vs Club 1st Division (p = 0.006), and recreational athletes (p = < 0.001); significantly greater incidence in premier club vs recreational players (p = 0.003); and significantly greater incidence in 2nd division club vs recreational players (p = 0.007). Post-hoc tests showed a significantly greater incidence of 'upper extremity' injuries in international vs recreational athletes (p = 0.045) and then, premier club vs 1st Division club (p = 0.045), 2nd division club (p = 0.032), University 2nd division (p = 0.014) and recreational (p = 0.001) players. No between-level differences were found for 'lower extremity' injuries, despite a significant result overall.

Table 9 - Statistical results showing the relationship between each predictor variable and the influence on injury location.

	Standing Height (cm)		***Body Mass (kg)***		***Starting Age (years)***		***Experience (years)***		***Position***			
Injury Location	***p***	**β**	***p***	**β**	***p***	**β**	***p***	**β**	***p***	**β**	**F (4,1460)**	**R^2**
Facial, Head and Neck	0.110	0.002	0.127	0.001	0.589	0.001	< 0.01*	-0.014	0.530	-0.010	12.030	0.036
Upper Extremities	0.228	0.002	0.017*	0.002	0.117	0.003	< 0.01*	-0.014	0.672	0.007	13.690	0.042
Midsection	0.360	0.001	0.452	< 0.001	0.041*	0.003	0.059	-0.003	0.314	-0.012	3.184	0.007
Spinal	0.604	< 0.001	0.516	< 0.001	0.363	< 0.001	0.298	< 0.001	0.963	< 0.001	0.878	< 0.001
Lower Extremities	0.942	< 0.001	0.124	0.001	< 0.01*	0.006	< 0.01*	-0.024	0.293	0.022	22.020	0.067

Table 10 - ANOVA (analysis of variance) results of the effects of the level of competition on the location of injuries

Hypothesis	***p***	***F (1,1463)***
Facial, Head and Neck	< 0.01*	12.59
Upper Extremities	< 0.01*	17.36
Midsection	0.274	1.198
Spinal	0.118	2.444
Lower Extremities	< 0.01*	9.796

(Table 11) shows the effects of body height, body mass, starting age, rugby experience, and competition levels on the grouped location in which the injury occurred, whilst accounting for differences in population size across playing levels. It was reported that 'experience' and 'body mass' still significantly influenced the incidence of 'facial, head and neck' injury incidence (Body mass (p = 0.048) Experience (p = 0.038). Whilst 'starting age' significantly influenced the incidence of 'midsection' injuries (p = 0.013).

Table 11 – ANCOVA results depicting the effects of Height, Body mass, Starting age, Experience, and competition level on the incidence rates of the types of injury when accounting for differences in population size for each different competition level

	Height		***Body mass***		***Age***		***Experience***	
	p	**F (1,1461)**	***p***	**F (1,1461)**	***p***	**F (1,1461)**	***p***	**F (1,1461)**
Face, Head and Neck	0.821	0.051	0.048*	3.912	0.964	0.002	0.038*	4.316
Upper extremities	0.772	0.084	0.84	0.041	0.349	0.878	0.181	1.795
Midsection	0.511	0.432	0.974	0.001	0.013*	6.252	0.057	3.616
Spinal	0.261	1.264	0.891	0.019	0.143	2.151	0.55	0.358
Lower extremities	0.358	0.845	0.389	0.741	0.058	3.587	0.529	0.396

Chapter 5: Discussion

5.1 Summary of Findings

Limited literature is available surrounding women's rugby union injuries. Thus, the purpose of this study was to gain a better understanding of the types of injuries that occur during women's rugby. Specifically, the influence of body mass, height, starting age, playing experience, position, and playing level on injury frequency, type, and location were examined. This thesis found that sprained ankles, concussions, fractured fingers, fractured noses, and ACLClick or tap here to enter text. tears were the top five most reported injuries, accounting for 48.7% of all injuries. These findings are consistent with the WRISP 20/21. Four of the top five injuries reported in this thesis were the same as the WRISP 20/21 report, except for fractured nose, which was replaced by posterior thigh muscle injuries in match injuries. For the WRISP 20/21 report, however, only included professional female rugby players in the Premier 15s who received appropriate medical attention and reporting, whereas this study focused on a global sample of women players from all playing levels. Additionally, differences in data collection methods between this thesis (self-reported survey) and the WRISP 20/21 report (medic-recorded injuries) does limit the value of this comparison. Furthermore, the WRISP 20/21 report grouped injuries by location, whereas in this thesis, injuries were differentiated individually.

In the men's game, data reports on the men's game start from 2002, with the PRISP specifically providing reports for the 2016-2017 through to the 2020-2021 seasons, which across the reports, show three of five most common injuries as: concussion, hamstring muscle injury and acromioclavicular (AC) joint injuries. Across the five reports, concussion remains the injury with the highest incidence. The PRISP reports focus solely on professional male players who are involved in the English Premiership and/or the English national team. There are consistencies across the high concussion incidence across both sexes. Similar findings were also present in youth rugby union. West et al., (2023) reported the most common injury site was lower extremities (males) and the head and neck (females). The most common injury type was ligament sprain (males) and concussion (females).

5.2 Physiological Implications for Reported Injuries

While there is a similarity in the injuries with the highest occurrence rates among males and females, it is important to investigate the underlying reasons behind the high incidence rates of concussion, ankle, and knee injuries specifically among female athletes and less so amongst male athletes. This is especially important since most medical focused research includes only androcentric data, that has led to a lack of understanding of female-specific anatomy, morphology, and disease treatment (Marts & Keitt, 2004).

5.2.1 Ankle Ligament Injury Incidence

A meta-analysis of 181 epidemiology studies of ankle sprains across a range of populations showed that the incidence of acute ankle sprains was higher in females when compared to their male counterparts (Doherty et al., 2014); with 13.6 vs 6.9/1000 exposures (Doherty et al., 2014). When focusing upon sporting population, that of rugby, elite male rugby players were found to report ankle ligament sprains as the injury with the fourth highest reported incidence (West et al., 2021b). West et al., (2021b) conducted a 16-season review of injury risk in professional male rugby union players, and reported that head & face, knee, and shoulder injuries all had higher incidences that ankle ligament sprains, unlike this study which focused on a global sample of women players, from all playing levels. The females in this thesis reported lower limb injuries, and more specifically ankle sprains, most frequently, with 1656 reported incidences totalling 24.3% of the total reported injuries. The findings of the current study compared well to those of previous studies. Ankle ligament sprains were the most reported injury type in elite female Rugby 7s tournaments, accounting for 36% of total injuries (17.0/1000 playing hours) (Ma et al., 2016). The findings in this thesis were in accordance with the WRISP 20/21. The WRISP 20/21 report indicates ankle injuries having the highest incidence in their elite population, which is consistent with the findings of this thesis, not only across the elite population (national team and premier club players for whom ankle ligaments sprains comprised 21.2% of their total injury incidence) but also across all playing levels and geographical regions.

Sexual Dimorphisms and Ankle Injuries

There are influences that explain why females are very susceptible to ankle sprains. Literature has highlighted that there are hormonal influences on the incidence rates of sprains between males and females, specifically around oestrogen. Beyond its function as a sex hormone, oestrogen has important roles in the development, maturation, and ageing of tissues such as connective tissues (Hansen, 2009). Lee, (2010) reported on the effects of oestrogen on ligaments. It was found that when mimicking the elevated levels of physiological oestrogen seen during the early follicular phase of the menstrual cycle, collagen production increased. A decrease of 80% was found in lysyl oxidase activity over 48 hours. This decrease reduces the stiffness of ligaments and in turn would provide less support for the ankle joint when under load. Therefore, increasing the risk of ligamental injury in females, especially during the follicular phase of the menstrual cycle.

Anatomically, females have been found to be able to produce on average 66% of the lower body strength that their male counterparts can produce (Miller, MacDougall, Tarnopolsky, & Sale, 1993). By having less muscle and subsequently being able to produce less force than their male counterparts. This in turn increases the risk of musculoskeletal injuries by having less support around their ankles when under load during sporting activities such as rugby.

These two crucial factors underscore the need for further research in women's sports, that is the potential impact of the menstrual cycle on injury incidence and the development of ankle strengthening protocols to mitigate the risk of ankle injuries in female athletes. Future studies should investigate the effect of menstrual cycle phases on injury incidence and explore ways to minimise injury risk during specific stages of the menstrual cycle. Additionally, research should focus on developing effective ankle strengthening protocols to help protect female athletes from ankle injuries. Addressing these areas of research will help reduce the negative impact of androcentric research and improve our understanding of the unique injury risks faced by female athletes.

5.2.2 Anterior Cruciate Ligament Injuries

Montalvo et al., (2019) reported females to have at least three times greater ACL injury rates than males in comparable field-based sports. In several sports, such as basketball, team handball, and soccer, female players have an alarmingly greater risk of ACL tears with the incidence of female to male is 3.5 times greater in basketball and 2.8 times greater in soccer (Ireland, 2002). Specific comparisons between male and female rugby players, however, are limited due to the androcentric focus of rugby injury literature, differences in professionalisation, physicality and participation rates. However, a five-year epidemiological study of injuries in a US service academy rugby club revealed the incidence rate of ACL injury was 5.3 times higher in women than men (Peck, Johnston, Owens, & Cameron, 2013). In this thesis, ACL injury incidence totalled 2.8% with it being reported as the 5th most common injury. The finding in the current study reflects that reported in the WRISP 20/21, with knee sprain / ligament injuries reporting to have the fourth highest incidence amongst those in the premiership 15s. The report also grouped knee sprains and ligament incidences together, which limits the inter-study comparisons.

Sexual Dimorphisms and Anterior Cruciate Ligament Injuries

Substantial evidence exists surrounding the risk factors of ACL injury incidence in females. Females have a wider pelvis, creating an increased quadriceps angle (Q-Angle) between the knee and hip joint (Merchant et al., 2020). This creates a more oblique angle which induces a greater lateral movement of the patella during quadricep contraction which puts females at a greater risk of knee injury (Conley, Rosenberg, & Crowninshield, 2007).

Coactivation of both the hamstring and quadricep muscle groups can protect the knee against both excessive anterior draw, knee abduction, and lower extremity valgus (Maniar, Cole, Bryant, & Opar, 2022). If there are deficits in strength and or activation of the hamstrings, this limits the potential for protective muscular co-contraction for the knee ligaments (Hewett, Myer, & Ford, 2006). Compared to males, females are found to have lower hamstring to quadricep peak torque contraction ratios (Hewett et al., 2005). Thus, females have a potentially reduced ability to adequately balance muscular recruitment during high impact loading.

For lower extremity injuries in combination with each other, the current study reports that none of the variable factors measured (height, body mass, starting age, or experience) have a significant influence on lower extremity injury incidence. It was also reported that despite the level of play having an overall considerable influence on lower extremity injury incidence, there were no significant differences between the individual playing levels. Therefore, the implications of these findings indicate that other external factors, such as those already provided by the previous literature e.g., anatomical, hormonal, muscular and external factors influence the rate of lower extremity injury incidence. An effective technique in reducing the risks associated with lower extremity injuries could be the design of a training intervention. This intervention may focus on improving the function of coactivation of the quadriceps and hamstrings as well as the muscles involved in the support of the ankle joint. Begalle, DiStefano, Blackburn, & Padua, (2012) investigated the coactivation ratios during specific lower limb exercises such as single leg deadlifts, to determine whether they are ideal in ACL rehabilitation and injury prevention. Their findings were that quadricep dominant exercises may negatively affect the knee by increasing ACL strain. Exercises with balanced quadriceps-to-hamstring coactivation ratio may benefit ACL rehabilitation. By using current literature such as that reported by Begalle, DiStefano, Blackburn, & Padua, (2012), it can be used to help direct future ACL specific injury prevention protocols.

5.2.3 Concussion Incidence

Concussion is the most frequently reported injury in elite male rugby union, and the second most commonly reported injury in this study across all playing levels, except for 2nd division university players. It accounts for 12% of the total injury count. The small sample size (n = 35) at 2nd division university compared the rest of the study population (n = 1430) is likely to skew these findings. Both the WRISP 18/19 and PRISP 19/20 reports, however, reported concussions to be the most common injury. The WRISP 18/19 reported concussion accounted for 19% of the total injuries, whilst the PRISP 19/20 saw concussion account for 22% of the total injuries.

There are several potential explanations for the differences between the literature and the results produced in this study. Unlike men's rugby union, women's rugby union has limited funding and therefore personnel available to them. Much like men's grassroots rugby union, most coaches and or medical staff will be volunteers in women's rugby including professional teams that reside in the top leagues, which during the period of which this studies' survey was undertaken, only three officially professional teams existed. Therefore, the type and frequency of medical advice provided by coaches and support staff will also vary differently across clubs and countries. In the context on the results found in this study, it was noted that the concussion rates were also lower than that published in the WRISP 18/19 and not just in comparison to that of the male game. One reason for this is highlighted in the fact that funding and medical provision is still extremely limited in the female game. Therefore, they potentially receive limited medical support.

A concussion is difficult to diagnose, with many symptoms of concussion such as confusion or dizziness being difficult to observe (Echlin et al., 2010; Moreau, Langdon, & Buckley, 2014). This therefore induces the potential for athletes to fail to report post head impact symptoms or be recognised by volunteer personnel and continue to play whilst concussed (Meehan, Mannix, Oêbrien, & Collins, 2013; Register-Mihalik et al., 2013; Delaney, Lamfookon, Bloom, Al-Kashmiri, & Correa, 2015; Torres et al., 2013). The advice given by these underqualified staff will follow the return to play advice without understanding the scientific evidence behind the advice. This has been seen in lower-limb injury prevention strategies (Twomey, Finch, Roediger, & Lloyd, 2009). Whilst a three-week post-concussion recovery period makes for a simple and easy implementation for many governing bodies, studies have found that this advice is not implemented consistently in non-professional rugby (Hollis, Stevenson, McIntosh, Shores, & Finch, 2012).

In recent years, rugby has seen changes in the management of concussion. In 2011, professional rugby in England adopted the six-stage graduated return-to-play (GRTP) guidelines, following modifications to World Rugby regulation. Each stage of the GRTP protocol must last at least 24 hours, with the final stage allowing a return to game play. This means the minimum time before a player can return to play is 6 days. Previously, World Rugby Regulation 10 required a three-week stand-down period unless cleared by a neurological specialist (West et al., 2021). The number of players returning to play before the recommended minimum time has improved significantly over time, but still remains an issue (West et al., 2021).

Alongside the inability to recognise concussion and implement safety protocols, environmental pressure from teammates, parents and fans have been found to incur lower intentional concussion reporting (Kroshus, Garnett, Hawrilenko, Baugh, & Calzo, 2015). Interestingly, coaches were not deemed to affect reporting rates, despite their perceived control over team selection (Kroshus, Garnett, Hawrilenko, Baugh, & Calzo, 2015).

However, it has been noted that coaches may indirectly influence reporting rates without overt verbal pressure by shaping the team's cultural norms about concussion safety via the communication of its importance (Kroshus, Garnett, Hawrilenko, Baugh, & Calzo, 2015). The lack of medical professionals, pressure from influential individuals and a lack of concussion education may lead to under reporting of concussions, and other injuries. This may explain why concussion was reported to occur less frequently in the current study, especially when compared to professional demographics**.**

Sexual Dimorphisms and Concussion Incidence

A limitation across all survey-based research is the reliance on the accuracy of the information reported by each individual. Research suggests that societal factors alone may not fully explain the disparities in concussion rates between males and females. Sex differences in cervical spine structure and mechanics contribute to increased rates of trauma-related neck pain in females (Cassidy et al., 2000). Females also exhibit greater physiologic and dynamic spinal motions (Lind et al., 1989; Stemper et al., 2004), indicating reduced cervical spine stiffness and lower cervical flexor and extensor strength (Borsa, Sauers, & Herling, 2002; Garcés et al., 2002).

Females have smaller vertebral geometry, leading to reduced head-neck column stability during external loading (Francis, 1955; Hukuda & Kojima, 2002; Katz et al., 1975), increasing the risk of head-neck injuries, including concussions. A study by Williams et al. (2021) found that maximal isometric neck strength was 47% lower in females compared to males, despite similar head impact magnitudes and a 24% difference in body mass. This supports previous research highlighting the practical implications for injury risk in females.

Although there may be variations in experience levels between male and female participants in studies, the literature consistently supports the role of sex in the observed strength differences.

5.3 Sex-Specific Equipment

5.3.1 Footwear Design and Ankle Stability

In addition to intrinsic factors, there are external factors that can impact the risk of ankle and foot injuries. It has been highlighted in the literature that designing women's sports shoes solely based on foot length, as smaller versions of men's shoes, may overlook important anatomical differences that can affect the risk of injury (Frey, 2000; O'Connor, Bragdon, & Baumhauer, 2006). Studies have shown that women have distinct foot characteristics such as lower instep height, increased ankle girth, lower first toe height, malleolus height, instep girth, and lateral/medial ball length compared to men, even when their foot length is similar (Wunderlich & Cavanagh, 2001). These differences emphasize the need to consider women's unique foot anatomy when designing footwear.

Given that ankle sprains are the most reported injury, accounting for almost a quarter of total reported incidents in this study, it is crucial to enhance our understanding of female ankle anatomy and function. It is important to consider the issue of ill-fitting shoes. This can be achieved by developing improved protocols. To accomplish this, a multidisciplinary approach is necessary, involving research, shoe design, fit assessment, education, and injury prevention programs. By adopting such an approach, we can effectively reduce the risk of ankle injuries and enhance the overall well-being of women participating in sports and physical activities.

5.3.2 Incorrectly Scaled Equipment

Finger fractures were the third most frequently reported injury in this thesis, similar to the WRISP report of 18/19 where it ranked fourth, but different from the PRISP 2020/21 report. It is important to note that the WRISP 18/19 report hand, finger, and thumb injuries together as a combined category, rather than as three separate Injuries. The discrepancy in injury rates between males and females may be attributed to a variety of different factors, with the most likely being the fact that the WRISP 18/19 group their injuries together. An avenue of potential influence however may be due to equipment scaling.

The absence of data on the mechanism of finger injury in the survey limits the conclusions that can be drawn from the study. Without information on how the finger injuries occurred, it becomes challenging to establish a definitive link between any factor and the differing injury rates. However, the fact that both men's and women's rugby use the same size 5 rugby ball, despite females having, on average, an 11% smaller hand span (Ruiz et al., 2006). Females can grip 8% less of the total ball circumference compared to males. This difference in hand size may impact skill acquisition and lead females to adjust in passing and catching techniques to compensate. The use of scaled equipment, such as a size four rugby ball, could potentially improve skill acquisition and overall gameplay for individuals whose physiology differs from the default male (Davids et al., 2008).

In a study by Gorman, Headrick, Renshaw, McCormack, & Topp (2021), it was found that inexperienced junior basketball players tended to choose basketball sizes proportional to their hand size. On the other hand, experienced players selected the ball size they were accustomed to, based on their prolonged experience, rather than choosing the size that offered the best functionality. This suggests that women's rugby players may be using a ball size that may not be functionally appropriate for their physical needs. This mismatch between equipment and hand size could increase the risk of finger injuries, as inexperienced players are required to adapt to equipment designed for larger male hands, which can strain the neuro-muscular system and increase the risk of injury. Therefore, while the survey results provide interesting insights, it is necessary to exercise caution in interpreting them as conclusive evidence of a risk factor. Further research that includes data on the mechanism of finger injury would be valuable in establishing more definitive conclusions.

5.4 Predictor Variables vs Injury Incidence

5.4.1 Rugby Starting Age

In this thesis, the age at which participants started playing women's rugby was found to significantly influence injury incidence. Specifically, in 'muscle and tendon,' 'midsection,' 'lower extremity' injuries, and overall injury incidence. Small positive beta coefficients were reported for these injuries, meaning that the older an individual is when they begin playing rugby, the more injuries they sustain. Despite the small positive beta coefficients, our findings do not agree with that reported in vast literature that focus on early specialisation in highly competitive sports. Early specialisation in sport has been associated with high rates of sports-related injury (DiSanti & Erickson, 2019; Jayanthi, Labella, Fischer, Pasulka, & Dugas, 2015). Especially in complex sports such as football or rugby, where player development is competitive. Ericsson, Krampe, & Tesch-Römer, (1993) state that early engagement is critical in developing technical prowess. In terms of an explanation for these findings, it may lie in both the demographics of the participants in this thesis, and the history of women's rugby. Firstly, Blagrove, Bruinvels, & Read, (2017) suggested that athletes should avoid single sport specialisation before the age of 13. Consistent with this recommendation, only 212 individuals from 1465 (14%) in this thesis started rugby before the age of 13. The small number of players engaging in early specialisation in this thesis may be explained by the up-and-coming structure in women's rugby.

White et al., (2022) conducted a review investigating which activities were compulsory in school in the UK. The opportunity for males to play rugby is widespread in schools, with 83% of schools making it compulsory, ranking it as the 8th most common activity (White et al., 2022). However, for females, only 54% of schools make rugby union compulsory, ranking it as the 18th most delivered activity (White et al., 2022). This indicates a significant gender disparity in the compulsory nature of rugby participation in schools. The lack of availability in schools is also seen in club opportunities. As of 2017, there were only 25,000 active registered female players in England, out of the total 359,447 registered players in England in 2017 (World Rugby, 2017). There are strategies such as the 'Every Rose Strategy' (England Rugby, n.d.) produced by the English RFU which spans between 2017 and 2027, with the aim to have 100,000 active registered female players, and at least 350 active clubs (in 2017) to introduce opportunities for female teams, all by 2027. World Rugby's Women's Plan 2017-2025 is also driving to increase female participation and engagement, with 2.7 million females participating globally amongst a total of 9.6 million players in 2018, with female participants up by 10% compared to 2017 (World Rugby, 2017). Despite the present efforts to drive participation, the fact that women's rugby union is still relatively new (The first fully sanctioned women's Rugby World Cup occurred in 1998, and the first team to become professional was in 2019) means the opportunity for women to participate in rugby from an early age has been limited up until now. This may influence the demographic of participants that were available for our study as many of them may not have had the opportunity to participate and / or specialise from a younger age.

Alongside societal and psychological influences, growth and maturation factors may also be large influences on injury incidence during adolescence. During adolescence, many physical and chemical changes occur which in turn can become several potential causes of increased injury risk. Growth rate during peak height velocity, changes to the mass and length of limbs, as well as moments of inertia may lead to increased risk of injury (Adirim & Cheng, 2003; Hawkins & Metheny, 2001). Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, (2012) reported that these physical changes consequently can cause temporary delays or even regression in an adolescent's sensorimotor control and mechanisms, in turn adversely affecting the risk of injury. When considering the literature, many of the individuals in this study may never have been given the opportunity to partake in early participation in rugby. Overlooking the higher injury risk during puberty and adolescence may lead to a result that differs from the widely reported literature. Therefore, future research in this area would be beneficial in examining the effect of early specialization in women's rugby on injury incidence. This could improve understanding of whether pubescent changes influence injury incidence and risk in female rugby players, and whether junior strength and conditioning programmes targeting prevalent adult injuries can lead to preventative strategies.

5.4.2 Rugby Experience

In this thesis, experience, including starting age, was found to statistically influence the incidence rate of various injury types and locations, as well as overall injury incidence. However, there is limited and conflicting evidence on the association between years of participation and sports-related injuries (Malone, Roe, Doran, Gabbett, & Collins, 2017; McCunn et al., 2017). Malone, Roe, Doran, Gabbett, & Collins, (2017) hypothesised that athletes who are new to a sport may lack transitional phases that prepare them for the movements and loads found in competition, potentially increasing their risk of injury. The current findings support this hypothesis, as all statistically significant multiple regressions in relation to experience showed negative beta coefficients, except for spinal injuries. This suggests an inverse correlation between experience and injury risk. However, more experienced athletes may have increased game time and, as a result, more opportunities for injury exposure compared to inexperienced athletes. Moreover, experienced players may be more prone to attempting riskier manoeuvres during play due to their increased skill set, which could increase the potential for injury. On the other hand, they may also have the experience to know when and how to reduce predisposition to injury through physical and psychological adjustments during training and competition. Therefore, future research should investigate the complex relationship between experience, injury risk, and injury prevention strategies in sports.

5.4.3 Competition Levels

This thesis revealed that the level of competition significantly influences the type of injuries that occur across different levels of competition. Specifically, bone and joint and ligament injuries differed across competition levels. In contrast, muscle and tendon injuries showed significant differences only between premier club and recreational players. Nervous and neural injuries exhibited differences between recreational players and all other levels. While previous literature (Gabbett, 2000; Gabbett, 2001; Stephenson, Gissane, & Jennings, 1996) has documented that injury incidence is increased at higher levels of competition, limited research has focused on how competition level in female rugby influences the types of injuries that occur.

Therefore, future research should investigate whether competition level affects the types of injuries that occur and the underlying reasons for these differences. This could inform injury prevention strategies across different levels of competition in rugby and other sports.

Current literature on the effect of competition level on the location of injury incidence is limited. A study by Musa et al., (2022) focused on the effect of competition level on the incidence rate in different injury locations of the body between amateur and elite tennis players. Noting that abdominal, arm, glute, groin, hand, leg, and neck injuries are found to be associated with elite players as opposed to amateur players. This present study also noted that there were significant differences in head, face & neck, upper extremity, and lower extremity injuries across various levels of competition. However, there are little to no studies that investigate these factors and in turn it is difficult to confirm if competition level affects injury location.

5.4.4 Body Mass

The results from this thesis imply that an increase in body mass increases the overall injury incidence, as well as those more specifically classified as upper extremity injuries. Gabbett, Ullah, & Finch, (2012) also reported that higher body mass was associated with increased injury risk in elite rugby league athletes. One limitation of the study published by Gabbett, Ullah, & Finch, (2012) is that there was a lack of evidence that subcutaneous body fat influenced the risk of contact injury. Previous studies have suggested that higher levels of subcutaneous fat stores may reduce the risk of contact injuries by providing an energy absorbing barrier (Meir, 1993). Other studies (Gabbett & Domrow, 2005) dispute these findings by reporting that those who are slower and with lighter body mass have an increased injury risk but highlight that it does not differentiate between fat-free mass and fat tissue, therefore limiting any conclusions. These findings, however, may be explained due to the lower competition levels having a greater heterogeneity in body mass which increases the likelihood of making one on one tackles with larger disparities in mass than that of more professional populations, and therefore an increased injury risk.

Acknowledging the effect of body mass upon upper extremity injuries, currently there is no available literature that help to support or disprove our findings. Gabbett, Ullah, & Finch, (2012) however, did report that athletes with poor upper-body strength had a higher incidence of contact injuries. Due to rugby athletes needing well-developed upper body strength to effectively perform wrestling, pushing, lifting, and pulling tasks involved in the tackle contest (Meir, Newton, Curtis, Fardell, & Butler, 2001). If an athlete has a reduced ability to continually develop and sustain the high impact forces required during tackling and wrestling places individuals at an increased risk of upper extremity injury.

Future research around the influence of body mass on injury risk are required to provide greater insight into the role of body mass on injury risk not just on elite athletes, but across all levels of competition.

5.4.5 Height

The results of this study highlighted that height was seen to significantly influence the overall injury incidence rate, with an increase in height seeing a minor increase in overall injury incidence. When isolating for different injury locations or types of injury, no significant influence was identified. Despite this finding, the relationship between height and injury incidence rate is not straightforward and can be influenced by numerous factors, including playing position, technique, strength, conditioning, and overall player skill (Theisen, Malisoux, Seil, & Urhausen, 2014). Chalmers, Samaranayaka, Gulliver, & McNoe, (2011) conducted a cohort study of 704 amateur male rugby union players across New Zealand and reported that height was not a risk factor upon injury incidence. Williams et al., (2017) reported that height had a trivial effect upon injury incidence when reviewing a seven-season study upon English premiership professional players. Considering the reported literature, the results of our study may be influenced by the idea that height like body mass was measured by different individuals, with different pieces of equipment which can lead to reporting / calibration error. Future research in this area would need to have a standardised method of measuring height to see the true effect of height in injury incidence.

5.4.6 Playing Position

As reported in this study, playing position was found to have no significant influence on the injury incidence rates, nor for the incidence rates for the different types or locations of injuries. Brooks & Kemp (2010) conducted a four-season study with 899 professional male rugby union athletes from 14 teams in the English premiership, to produce an injury profile for each different playing position. Brooks & Kemp (2010) concluded that there were no significant differences in the injury incidence rates between forwards and backs. Whilst this is comparable with our study and other epidemiological studies (Bird et al., 1998; Brooks, 2005; Quarrie, 2001), these findings are based upon professional male populations only. Therefore, limiting the comparison that can be made between the findings. A further limitation in relation to this study is that participants were asked to provide all positions they have participated in. This in turn caused participants to be categorised into either forwards or backs, based upon the positions listed; or if they provided an equal number or forward or back positions, this led to them being categorised into a third category of both. By categorising the participants this way, they may be categorised as a back, when in fact the participant played most of their time as a forward and sustained most of their injuries as a forward for example. To further understand the effect of playing positions on injury incidence rates and profiles in female athletes, more in depth research is required in the future to help determine whether positions need to be focused upon, and subsequently develop ways to reduce the risk of these injuries occurring.

5.5 Conclusion

The sex differences in injury incidence rates and injury profile observed in this study emphasise that male-derived injury prevention data cannot be generalised to female athletes. The study highlights that female rugby players have an increased risk of ankle, knee, and concussion-related injuries. Furthermore, starting age and experience are key factors that can alter the risk of injury incidence for individuals. These results underscore the need for more research to identify and understand specific sex-based injury risks in female rugby athletes and to develop appropriate intervention strategies to reduce injury risks. Additionally, our understanding of non-scalable sex differences in cervical spine geometry and function, and knee geometry and function can be used to explore other sexual dimorphisms, such as ankle stability. Furthermore, it is important to investigate whether an androcentric focus in research has influenced equipment provision and whether this is appropriate based on current literature. Improving the accessibility of rugby union to females and providing appropriate levels of funding, coaching and research may be the key to helping to progress our understanding of these non-scalable differences. This may also reduce the effect of our past societal naivety in assuming that males and females are the same, by providing a much safter environment for females to participate in.

5.5.1 Study Limitations

Methodological limitations have been identified within our study. Firstly, the way in which we delivered questions used within survey have limited the exploration of the available data. In relation to experience, by asking for how many years an individual has played for, rather than asking for how many injuries they sustained in each year of participation, this limits the interpretations that can be made from the results. Another question under scrutiny revolves around question 26 "During your rugby career, please list the injuries you have sustained and the number of times you have suffered each injury (e.g., torn hamstring *2, sprained ankle * etc.)". During data cleaning, many unclear responses lead to data being excluded which may have impacted on the quality of the data. Further to this, many individuals may not have had access to medical professionals who accurately diagnose and retain injury records. This can cause either under or over reporting of injuries and therefore misrepresenting the results. One final limitation in relation to the types of questions asked resides in the playing level categorisation. Individuals were categorised into the level that best represented the response they had given. Individuals who specialise in rugby in particular countries where the structure of competition remained unclear to help best categorise participants' playing level. The intensity and standard in one league may not be representative of that same league played in another country. This may cause increases or decreases in injury responses and influence the results of the study.

Another limitation of this study arises through its design; as this study is a retrospective study by nature, it requires the study population to recall details for the data to be collected for the study. This in turn introduces a systematic error known as "recall bias" (Coughlin, 1990). Patients may not be able to correctly recollect or describe the specifics, thus certain aspects may be changed or removed. Smith, Bibi, & Sheard

(2003), highlight that an individual's ability to recall an event depends on the magnitude of the effect of that event on that individual. Thus, an event of lesser impact, say a dead leg, may not be as accurately recalled in comparison to an event such as a dislocated shoulder. The human memory is not perfect and therefore the data collected from recollection must not be relied upon as 100% accurate (Talari & Goyal, 2020).
Another limitation arises through the inclusion of transgender athletes. The number of transgender athletes in this study was small (n = 11) in comparison to the total study population, therefore meaning the effect of their results will be minimal. While this study focused on women's rugby, it assumed that participants were biologically female, but did not exclude participants identifying as transgender. As these individuals were biologically male at birth, their deep structural physiology differs to biological females.

5.5.2 Future Research

Alongside the recommendations mentioned already throughout the discussion, the following research questions / areas need to be addressed to help provide and determine the future direction of injury intervention and prevention strategies in women's rugby union.

1. Are there underlying physiological mechanisms that increase the risk of ankle injuries in females?
2. Are there any underlying issues in women's rugby equipment such as shoes that may influence the risk of injury?
3. A review into current training programmes in women's rugby union and whether they are effective in identifying areas of increased injury risk such as ACL, concussion, ankle sprains and providing correct program memes to help minimise the risks, and whether any specialised preventative action is needed?
4. Are the current ball sizes the most appropriate size for women's rugby union?
5. Are current concussion protocols found in men's rugby union appropriate in women's rugby union protocols?

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Appendices

Appendix A. Survey Questionnaire

Women’s Rugby Union Player Survey Questionnaire 2020

Thank you for your time in taking part in the women’s rugby union survey for 2020. The objective of this survey is to help to bridge the substantial gender data gap which exists in medical and sport science, particularly in contact sports. You are free to contact the research team at any time for any questions or ideas (details below):

PARTICIPANT INFORMATION SHEET - PLAYERS (Version 1.1, Date: 29 /06/2020)

Project Title:

Building an Evidence Base for Women-Specific Training and Injury Identification in Rugby Union – Global Questionnaire

Contact Details:

Dr Elisabeth Williams, ASTEM, College of Engineering, Bay Campus, Swansea University, Fabian Way
Swansea, SA18EN, United Kingdom, [redacted]

Alternative Contact Details:

Dr Anna Stodter - a[redacted]
Dr Izzy Moore - [redacted]
Dr Genevieve Williams - [redacted]

Invitation Paragraph

My name is Dr Elisabeth Williams and I am a senior lecturer in applied biomechanics at Swansea University in Wales, U.K. On behalf of the research team listed above, we would like to thank you for your time and interest in completing this questionnaire.

What is the purpose of the study?

The aim of this survey questionnaire is to gather data about women rugby players who participate at all levels; local club, university, elite, professional and international. You will be aware that professionalisation of women's rugby has come 33 years after the male game. Currently, worldwide women's participation in rugby is rising by 28% per year, with 2.7 million registered players at the end of 2018. As rugby has historically been a male-dominated sport, most research about training techniques and injury risk has focused on male athletes.

Male-based findings in sports and medicine are routinely generalised to women, even when there is little to no evidence about how women respond. This has created a significant gender data gap, and training programs are a good example of this. What this ultimately means is 'women are not small men' and we need to ensure we are training women appropriately to make them better, safer athletes. This very much applies to sports related mild traumatic brain injury (mTBI), which is a serious problem in contact sports like rugby.

There are many physical differences between males and females, in addition to playing opportunities and access to expert coaching, which may compromise the safety and performance of women rugby players. Reports have shown women to be 2.6 times more likely to suffer a concussion in sport. Research shows that female athletes take longer to return to play, have worse symptoms and are more likely to report dizziness, fatigue and difficulty concentrating than males. Differences between male and female head/neck physiology, neck strength and neuronal structure in the brain have been linked to a greater head injury severity in females following rugby impacts.

Why have I been chosen?

You have been approached via women's rugby social media platforms to participate in this study as you are a women's rugby player, over the age of 18. We would like to know about your experiences, the anthropometrics of different playing positions, injury patterns and health monitoring practices in particular. The data you provide will help us to create an evidence base to develop targeted, women- specific interventions to improve player safety. We hope to have as many women rugby players as possible complete this survey in order to build a valuable and informative dataset that we can all benefit from.

Taking part in this study is entirely voluntary. The questionnaire responses are completely anonymous, even to the research team. **As your responses for each question are automatically saved when you answer them, and no identifiable information is recorded in this study, we are unable to withdraw your data once you have provided a response.**

What will happen to me if I take part?

Participation in this study involves completing the anonymous questionnaire which follows this document, after you click to confirm that you are over 18, fit the criteria for the study and agree to participate. The questionnaire is in three sections:

- **Section One:** Demographics, playing experience and positions, playing level and basic health information.
- **Section Two:** Concussion history, strength and conditioning, injury prevention training and injury management.
- **Section Three:** Women-specific concussion symptoms, the effects of menstrual cycle on training, performance and injuries, female physiology, medical support and financial resources in women's rugby union.

The questionnaire should take you approximately ten minutes for section 1 and depending on the length of your answers, 15-20 minutes each for sections 2 and 3. By answering all the sections of the questionnaire, you will help us to tackle the significant gender data gap.

What are the possible disadvantages of taking part?

Some questions will ask you about previous concussions or possible concussions you may have had, both while playing rugby and in other aspects of your life. This may trigger upsetting memories, depending on the circumstances surrounding your injuries. If you do feel upset by any content in the questionnaire, you are advised to contact someone you trust and you are always welcome to contact anyone from the research team, whose email addresses are provided above.

What are the possible benefits of taking part?

By taking part in this study, you will be making an invaluable contribution to the much-needed knowledge about women's rugby union. This information will be used to improve training strategies to minimise the risk of brain injury to women rugby players and other contact sport athletes. The data gathered from this questionnaire will also help us understand what most women rugby players know about how their bodies respond to trauma and to different training stimuli at different phases of the menstrual cycle. With that information we can work with rugby organisations to improve training practices and guidelines specific to women athletes. In addition to publishing our generalised findings in open-source journals, we will be making our generalised findings available on Twitter: (@TBI- ResearchNet).

Will my taking part in the study be kept confidential?

Due to the nature of this anonymous survey, your identity will not be recorded. The anonymised data will be kept by the research team and used both directly in publishable studies and as pilot information for three years. After this date, the data will be stored for a further four years for reference for future work in this area. All anonymised data will be kept on a secure cloud platform, accessible only by the research team.

Here is a news article link from early 2020 to provide you with more context for this study:
https://www-bbc-co-uk.cdn.ampproject.org/c/s/www.bbc.co.uk/news/amp/uk-wales-51434749

Data Protection and Confidentiality: Your data will be processed in accordance with the Data Protection Act 2018 and the General Data Protection Regulation 2016 (GDPR). All information collected about you will be kept strictly confidential. Your data will only be viewed by the researcher/research team. All electronic data will be stored on a password-protected computer file at Swansea University. Your consent information does not require your name to eliminate risk in the event of a data breach. Please note that as data is being collected online, once the data has been submitted online you will be unable to withdraw your information. **Data Protection Privacy Notice:** The data controller for this project will be Swansea University. The University Data Protection Officer provides oversight of university activities involving the processing of personal data and can be contacted at the Vice Chancellors Office. Your personal data will be processed for the purposes outlined in this information sheet. Standard ethical procedures will involve you providing your consent to participate in this study by completing the consent form that has been provided to you. The legal basis that we will rely on to process your personal data will be necessary for the performance of a task carried out in the public interest. This public interest justification is approved by the College of Engineering Research Ethics Committee, Swansea University. The legal basis that we will rely on to process special categories of data will be processing is necessary for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes. **How long will your information be held?** We will hold any personal data and special categories of data for seven years. **What are your rights?** Please visit the University Data Protection webpages for further information in relation to your rights. Any requests or objections should be made in writing to the University Data Protection Officer:- University Compliance Officer (FOI/DP), Vice-Chancellor's Office, Swansea University, Singleton Park, Swansea, SA2 8PP, Email: dataprotection@swansea.ac.uk **How to make a complaint:** If you are unhappy with the way in which your personal data has been processed, you may in the first instance contact the University Data Protection Officer using the contact details above. If you remain dissatisfied, then you have the right to apply directly to the Information Commissioner for a decision. The Information Commissioner can be contacted at: - Information Commissioner's Office, Wycliffe House, Water Lane, Wilmslow, Cheshire, SK9 5AF, www.ico.org.uk **What if I have any questions?** Further information can be obtained from the researcher contact stated above. Also state that the project has been approved by the College of Engineering Research Ethics Committee at Swansea University. If you have any questions regarding this, any complaint, or concerns about the ethics of this research please contact Dr Andrew Bloodworth, Chair of the College of Engineering Research Ethics Committee, Swansea University. [redacted]. The institutional contact for reporting cases of research conduct is Registrar & Chief Operating Officer Mr Andrew Rhodes. Email: researchmisconduct@swansea.ac.uk. Further details are available at the Swansea University webpages.

PARTICIPANT CONSENT FORM (Version 1.1, Date: 29/06/2020)

I confirm that I have read and understood the information sheet dated 29/06/2020, version number
1.1 and that I have the opportunity to contact members of the research team to ask questions. I understand that my participation is voluntary, and the questionnaire responses are completely anonymous, even to the research team. I understand that my responses for each question are automatically saved when I answer them, and no identifiable information is recorded in this study. I understand that I am unable to withdraw my data once I have provided a response. I understand that data obtained may be looked at by responsible individuals from Swansea University or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to these records. I understand that data I provide may be used in reports and academic publications in anonymous fashion.

I agree to take part in the above study: YES (please circle)

Section 1

1. What country are you based in?

2. Please state the team or teams/region you currently play for (optional)?

3. What is your current age (years)?

4. What is your height (cm)?

5. What is your body weight (kg)?

6. At what age did you start playing rugby?

7. How many years have you been taking part in rugby matches?

8. Please circle what best describes your playing level(s) (select all that apply)
    - Recreational
    - University second division
    - Club second division
    - University first division
    - Club first division
    - Premier club
    - International
    - Other (please provide further details)

9. What are your current/most recent playing positions (1 to 15)

10. Do you play Rugby Sevens? (please circle)

- Yes
- No

11. What are your current/most recent playing positions (1 to 7)

12. Do you currently compete in any other sport in addition to rugby? (please circle)

- Yes
- No

13. Please state your other sport(s):

14. How long have you been competing in this sport(s)? (please circle)
    - Less than one year
    - 1-3 years
    - 4-6 years
    - 6-10 years
    - 10+ years

15. What level do you compete at in your other sport(s)? (please circle)
    - Recreational
    - University
    - Club first division
    - Premier club
    - International
    - Other (please provide further details)

16. Prior to playing rugby, did you compete in any other sport? (please circle)
    - Yes
    - No

17. Please state your other sport(s):

18. How long did you compete in this sport(s)? (please circle)

- Less than one year
- 1-3 years
- 4-6 years
- 6-10 years
- 10+ years

19. At what level did you compete in your other sport(s)? (please circle)

- Recreational
- University
- Club first division
- Premier club
- International
- Other (please provide further details)

20. Are you familiar with the term concussion? (please circle)

- Yes
- No

21. Which of the following are common signs of concussion? (please circle all that apply)

- Arm pain
- Chest pain
- Confusion
- Cut to the face
- Difficulty concentrating
- Dizziness
- Drowsiness
- Feeling or being sick
- Headache
- Knocked out
- Memory loss
- Neck pain
- Nosebleed
- Stomach cramps

22. Please select all statements you think are true/correct: (please circle all that apply)

- Concussion is caused by an impact to the head

- Concussion is caused by an impact to the body
- Concussion only happens when a person is knocked out/loses consciousness
- Concussion only happens in rugby/contact sport
- Concussion can be caused by a direct or indirect blow to the head
- Most concussions don't involve loss of consciousness
- All concussions get reported and documented
- Most concussions go unreported and undiagnosed

23. Have you received any concussion education through your rugby team? Please select all that apply to you. (please circle all that apply)

- None, it's never been mentioned
- My coach has talked to me about it on one or two occasions
- A member of the medical team has talked to me about it on one or two occasions
- I have had a concussion seminar in the past
- I have taken part in concussion seminars every season
- I have completed an online concussion education program every season (such as World Rugby Concussion Management)
- Other (please provide further details)

24. Have you ever had a concussion while playing rugby? (please circle)

- Yes
- No
- I don't know

25. How did the concussion(s) happen? (select all that apply, for example: I was the tackler AND hit my head on the ground) (please circle)

- I was tackled
- I was the tackler
- I was in a ruck
- My head collided with another player's head
- My head collided with another player's shoulder bone/hip bone/knee bone/foot)
- My head collided with another player's soft body part (.g. stomach)
- My head collided with the ground
- I don't know

- Other (please provide further details)

26. At what age did you experience this/these concussion(s)? (circle all that apply)

- Under 10 years
- 11 - 13 years
- 14 -16 years
- 17 - 19 years
- 20 - 24 years
- 25 - 29 years
- 30 - 34 years
- 35 - 39 years
- 40 - 44 years
- 45 - 49 years
- 50+ years

27. Was/were your concussion(s) diagnosed by a medical professional? (please circle)

- Yes
- No

28. Was your concussion reported to a medical professional? (please circle)

- Yes
- No

29. Why was your concussion not reported to a medical professional? (please circle)

- I chose not to report it
- I did not realise at the time
- I didn't think it needed medical attention, it would just get better with rest
- Other (please provide further details)

30. Have you ever had a concussion while taking part in other sports? (please circle)

- Yes
- No
- I don't know

31. In which sport(s) did this/these concussion(s) happen and how did it happen?

32. At what age(s) did you experience this/these concussion(s)? (select all that apply)

- Under 10 years
- 11-13 years
- 14 - 16 years
- 17 - 19 years
- 20 - 24 years
- 25 - 29 years
- 30 - 34 years
- 35 - 39 years
- 40 - 44 years
- 45 - 49 years
- 50 + years

33. Was it diagnosed by a medical professional? (please circle)

- Yes
- No

34. Was your concussion reported to a medical professional? (please circle)

- Yes
- No

35. Why was your concussion not reported to a medical professional? (please circle)

- I chose not to report it
- I did not realise at the time
- I didn't think it needed medical attention, it would just get better with rest
- Other (please provide further details)

36. Have you ever / do you think you have ever had a concussion while taking part in other activities or any aspect of your life? (please circle)

- Yes
- No
- I don’t know

37. At what age(s) did you experience this/these concussion(s)? (circle all that apply)

- Under 10 years
- 11-13 years
- 14 - 16 years
- 17 - 19 years
- 20 - 24 years
- 25 - 29 years
- 30 - 34 years
- 35 - 39 years
- 40 - 44 years
- 45 - 49 years
- 50 + years

38. Was it diagnosed by a medical professional? (please circle)

- Yes
- No

39. Why was your concussion not reported to a medical professional? (please circle)

- I chose not to report it
- I did not realise at the time
- I didn’t think it needed medical attention, it would just get better with rest
- Other (please provide further details)

40. Under what circumstances or taking part in what activity did this occur (e.g fall from bike/horse, altercation, car accident)?

41. How many concussions do you think you have had during your rugby career? Please note that many concussive injuries are unreported and undiagnosed.

Section 2

1. When you first started playing rugby, do you feel you were given sufficient contact training before your first match to ensure safe and effective contact?

    - Yes
    - No
    - Other (please provide further details)

2. When you first started playing rugby, before your first match, approximately how many hours of full contact training were you given in total?

    - None
    - One session of contact/tackle training
    - Two sessions of contact/tackle training
    - Three to five sessions of contact/tackle training
    - Approximately one month of regular contact/tackle training
    - Approximately two months of regular contact/tackle training
    - More than two months of regular contact/tackle training
    - Other (please provide further details)

3. When you first started playing rugby, how confident did you feel with regard to contact technique and contact intensity going into your first match?

    - Not confident at all (0/5)
    - A little confident (1/5)
    - Somewhat confident (2/5)
    - Relatively confident (3/5)
    - Comfortably confident (4/5)
    - Very confident (5/5)
    - Other (please provide further details)

4. When you started playing rugby, did you complete any training on how to fall or land on the ground?

    - Yes
    - No
    - Other (please provide further details)

5. Has this falling technique training been completed again since you first started playing?

    - No
    - Yes, once per season
    - Yes, once per month
    - Yes, weekly
    - Other (please provide further details)

6. What was the fall techniques recommended (parachute, land on front, side etc), if you are unsure of the terms, please give a brief description:

6. In general, how long is your pre-season training block for your regular team? (from the time the players meet as a group)

    - Training is only completed within the season
    - One to two weeks (training less than 3 times per week)
    - Three to six weeks (training less than 3 times per week)
    - One to two weeks (training 3+ days per week)
    - Three to four weeks
    - Five to six weeks
    - Other (please provide further details)

7. What does your pre-season training typically include? (select all that apply)

- Running endurance and speed
- Strength and gym work
- Ball/passing skills
- Team tactics
- Contact drills and/or tackle technique
- Falling technique and/or body awareness training
- Active recovery sessions
- Other (please provide further details)

8. During the pre-season how many days rest from training do you have?

- 1
- 2
- 3
- Other (please provide further details)

10. Approximately how many hours of contact activities (tackling, tackle technique, rucking etc.) do you do each week during the playing season for your regular team?

- None
- Less than one hour per week
- One dedicated contact session per week
- Two dedicated contact sessions per week
- Three dedicated contact sessions per week
- Four + dedicated contact sessions per week
- Other (please provide further details)

11. Approximately how many hours of non-contact training (team fitness, passing, skills, agility drills, touch rugby) do you do each week during the playing season for your regular team?

- None
- Less than one hour during the week
- One dedicated non-contact session per week
- Two dedicated non-contact sessions per week
- Three dedicated non-contact sessions per week
- Four + dedicated non-contact sessions per week
- Other (please provide further details)

12. Approximately how many hours of strength training (weights, plyometrics etc.) do you do each week during the playing season with your regular team?

- None
- Less than one hour during the week
- One dedicated non-contact session per week
- Two dedicated non-contact sessions per week
- Three dedicated non-contact sessions per week
- Four + dedicated non-contact sessions per week
- Other (please provide further details)

13. Alongside your rugby training how many hours per week do you spend doing your own physical training during a typical week during the rugby season?

- None
- Up to one hour
- Up to two hours
- Up to three hours
- Up to four hours
- Up to five hours
- Up to six hours
- Up to seven hours
- Up to eight hours
- Up to nine hours

- Up to ten hours
- More than 10 hours
- Other (please provide further details)

14. Of these hours you spend doing your own additional training, approximately how many hours do you spend doing strength/weight training?

15. Of these hours you spend doing your own additional training, approximately how many hours do you spend doing endurance/aerobic training?

16. Of these hours you spend doing your own additional training, approximately how many hours do you spend doing speed/sprint training?

17. Of these hours you spend doing your own additional training, approximately how many hours do you spend doing agility/coordination training?

18. Do you use any recovery strategies after training/games? (select all that apply)

- None
- Yoga
- Hot/Cold water immersion
- Leg compression
- Sports Massage
- Other (please provide further details)

19. Typically (in a normal year) how many hours per week during your **off-season** do you spend doing your own physical training?

Of the time you spend doing your own physical training during a typical off-season, how many hours per week would be **strength/weight training?**

Of the time you spend doing your own physical training during a typical off-season, how many hours per week would be **endurance/aerobic training?**

Of the time you spend doing your own physical training during a typical off-season, how many hours per week would be **speed/sprint training?**

Of the time you spend doing your own physical training during a typical off-season, how many hours per week would be **agility/coordination training?**

Of the time you spend doing your own physical training during a typical off-season, how many hours per week would be **contact/tackle training?**

20. How many hours of sleep do you usually get each night?

- Less than 6
- 6
- 7
- 8
- 9
- 9+
- Other (please provide further details)

21. Do you regularly sleep / have a nap during the day?

- Yes
- No
- Other (please provide further details)

22. Do you have a regular sleep/wake time?

- Yes
- No
- Other (please provide further details)

23. How long do you have off all training at the end of the rugby season?

- <1 week
- 1-2 weeks
- 3-4 weeks
- 5-6 weeks
- Other (please provide further details)

24. During your rugby career, have you received any education about the role of neck strength in minimising concussion injuries?

- Yes
- No
- Other (please provide further details)

25. Have you ever done training focused on improving neck strength?

- No and I'm not interested in doing it
- No, but it's something I would be keen to try in the future
- Yes, our coaches encourage us to do basic neck strength exercises
- Yes, I do bodyweight neck strengthening exercises
- Yes, I do weighted neck strengthening exercises

26. During your rugby career, please list the injuries you have sustained and the number of times you have suffered each injury (e.g. torn hamstring *2, sprained ankle *1 etc.) and how you think these happened (e.g. tackle, fall etc).

27. Following a previous rugby bodily injury (**excluding possible concussion**), did you feel you received adequate pitch-side medical provision in terms of injury identification?

- Yes
- No
- Not applicable
- Other (please provide further details)

28. Following a rugby injury (**excluding possible concussion**), did you feel you received adequate pitch-side medical provision in terms of Injury management:

- Yes
- No
- Other (please provide further details)

(if no)

29. Were you referred for further clinical assessment?

- Yes
- No

30. When you return to play after a bodily (non-head) injury, are you confident that you are fit enough to play:

- Yes - I feel fully recovered
- Yes - I followed a full return-to-play protocol guided by a medical team
- Yes - I don't feel quite right but I think my injury will survive an upcoming match
- No - but I tried to play through it
- Other (please specify)

31. Following a previous rugby **head injury or concussive** injury, did you feel you received adequate medical provision in terms of injury **identification:**

- Yes
- No
- Not applicable
- Other (please provide further details)

32. Following a previous rugby **head injury or concussive injury**, did you feel you received adequate medical provision in terms of injury **management:**

- Yes
- No
- Not applicable
- Other (please provide further details)

33. Following a previous rugby **head injury or concussive injury**, did you feel you received adequate medical provision in terms of injury **rehabilitation:**

- Yes
- No
- Not applicable
- Other (please provide further details)

34. When you return to play rugby after a head injury or concussion, are you confident that you are fit enough to play?

- Yes - I feel fully recovered
- Yes - I followed a full return-to-play protocol guided by a medical team
- Yes - I don't feel quite right but I think my injury will survive an upcoming match
- No - but I tried to play through it
- Other (please provide further details)

35. Who develops/designs, promotes & manages your return to play (RTP) following injuries?

- Team doctor
- Team physio
- My own doctor (separate to team)
- My own physio (separate to team)
- Coaches - we just have a conversation
- Teammates - encouragement to come back
- I manage it myself, mostly based on how I feel and I decide
- Not applicable
- Other (please provide further details)

36. If you were concussed during a game, would you be able to recognise it?

- Yes
- No
- I don’t know

37. If you suspect that you have suffered a concussion during a rugby match in the past, did you:

- Continue playing as normal
- Continue playing but trying to stay out of heavy contact
- Remove yourself from play
- Get removed from play by a coach/medic/team mate
- I’ve never suspected I had a concussion during a match
- Other (please provide further details)

38. If you suspected your teammate had a concussion in a rugby game, would you report it?

- Yes
- No
- I don’t know
- Other (please provide further details)

39. When you play matches with your regular team, is there a medical professional present to identify suspected concussions

- Yes
- No
- I don’t know
- Other (please provide further details)

40. If you have suffered a previous concussion, how long do you think it took for you to fully recover (feeling as well as you did before the injury, with no concussion symptoms present)

- Within 1 week
- Within 2 weeks
- Within 1 month
- Up to 3 months
- Beyond 3 months
- I am not the same as I was before the concussion/I have not fully recovered

42. Following a concussion have you felt pressure from your teammates to return to play

- Yes - it probably shortened the time spent out of training/games
- Yes - it did not affect the time it took me to return to play
- No, I did not feel pressure from anyone to return to play

43. Following a concussion have you felt pressure from your coaches to return to play

- Yes - it probably shortened the time spent out of training/games
- Yes - it did not affect the time it took me to return to play
- No, I did not feel pressure from anyone to return to play

44. When you have been concussed (or you or someone else thinks you've been concussed), do you put yourself under pressure to return to play?

- Yes
- No
- Not applicable
- Other (please specify)

45. What is the top reason for returning to play?

- I don’t like to miss games
- I miss the social network
- Without me my team will not win
- Other (please provide further details)

46. Have you ever felt unduly/exceptionally tired, irritable, confused, had concentration problems or other concussion symptoms following a match?

- Yes
- No

47. Did you tell your coach?

- Yes
- No

48. What was your coach's response to you telling them about these symptoms?

- Yes, they brushed off my symptoms, encouraged me to continue playing/training
- Yes, they allowed me to decide on whether I continued playing/training
- Yes, they removed me from game/training and suggested I seek medical advice
- Yes, they actively helped me seek medical advice
- No, I didn't feel I could inform my coach
- Other (please provide further details)

49. If you have previously experienced concussion, were you asked what phase of your menstrual cycle you were in?

    - Yes
    - No
    - Not applicable
    - Other (please provide further details)

50. In your experience, do you think that the phase of your menstrual cycle can affect the severity of concussion symptoms and your subsequent recovery?

    - Yes
    - No
    - I don't know
    - Other (please provide further details)

51. Are you aware of World Rugby's concussion return to play (RTP) guidelines?

- Yes
- No

52. What is the minimum amount of time before you can RTP following a concussion?

- I think I can go back straight away
- At least 1 week
- At least 10 days
- At least 2 weeks
- At least 3 weeks
- At least 4 weeks
- Other (please provide further details)

52. In your opinion, what do you think is the most common mechanism of head impact in women's rugby at the level you play at? For example, either direct contact to the head (with the head, knee, hip etc. of another player, the ground) or sharp head acceleration from indirect contact?

Section 3

1. Were you assigned the biological sex of female at birth?

    - Yes (please skip to Question 3)
    - No
    - Other (please provide further details)

2. If no, are you currently undergoing hormonal treatments or have you ever?

    - Yes
    - No
    - Other (please provide further details – please provide details of timeframes and dosages and any further details you believe to be relevant)

Have you ever competed in sport in a male category?

- Yes
- No

If you answered yes to Question 1 of Section 3, please skip to Question 30.

3. Do you use hormonal contraception?

    - Yes
    - No

(if YES to Question 3, please continue, if NO to Question 3, skip to Question 15)

4. What form of hormonal contraceptive do you use?

- Combined oral
- Progesterone only (Mini Pill)
- Contraceptive patch
- Contraceptive Injection
- Contraceptive Implant
- Intrauterine device (IUD)
- Other (please provide further details)

5. How long have you used hormonal contraceptives for?

- <1year
- 1-3years
- 3-5years
- 5 years +

6. Do you experience bleeding? (referred to as withdrawal bleeds)

- Yes
- No

If you answered YES to Question 6, please continue, if you answered NO to Question 6, please skip to Question 10

7. Do you continue to train and play during your withdrawal bleed?

- Yes
- No
- Other

8. Do you take medication to manage symptoms caused by your withdrawal bleed during training/games?

- Yes
- No

(if yes to Question 8)

9. Which medications do you take to manage these symptoms?

- Paracetamol
- Co Codamol
- Naproxen
- Ibuprofen
- Other (please provide further details)

10. Do you track your reproductive cycle, which of the following applies to you?

- I track my cycle and relate this to my training program
- I track my cycle but don't relate it to my training
- I don't track my cycle
- Other (please provide further details)

11. What symptoms of the reproductive cycle do you feel affect your training and performance? (please state below)

12. Do you feel that your performance is altered when playing due to symptoms related to taking contraceptives?

- Yes
- No
- Other (please provide further details)

(if yes)

13. Why do you feel that your performance is altered when playing due to symptoms related to taking contraceptives? (state below)

14. Do you use hormonal contraceptives to be able to control or stop your periods due to playing rugby?

- Yes
- No
- Other (please provide further details)

If answered contraceptive questions, skip to Question 26

15. Do you have a regular menstrual cycle?

- Yes
- No
- Other (please provide further details)

16. How often do you have a period?

- 15-20 days
- 21-35 days
- 35 - 60 days
- Once or twice per year

- Less than once a year
- Not for the previous two years

17. Is the duration between your periods always the same length of time (±7 days)?

- Yes
- Sometimes
- Rarely
- Never

18. Do you continue to train/compete during your period?

- Yes
- No
- Other (please provide further details)

19. Do you track your menstrual cycle, which of the following applies to you?

- I track my cycle and relate this to my training program
- I track my cycle but don't relate it to my training
- I don't track my cycle

20. Do you take medication to manage symptoms caused by your period during training/games?

- Yes
- No
- Other (please specify)

21. If Yes, which medications do you take? (select all that apply)

- Paracetamol
- Co Codamol
- Naproxen
- Ibuprofen
- Other (please provide further details)

22. Do you feel that your training/performance is **enhanced** at certain times during your menstrual cycle/period?

- Yes
- No
- I don’t know

(if yes)

23. When do you feel your performance is enhanced?

- In the week before your period
- During your period (when bleeding)
- The week following your period
- Other (please provide further details)

24. Do you feel that your training/performance is **impaired** at certain times during your menstrual cycle/period?

- Yes
- No
- I don’t know

(if yes)

25. When do you feel your performance is **impaired**?

- In the week before your period
- During your period (when bleeding)
- The week following your period
- Other (please provide further details)

26. What symptoms of the menstrual cycle do you feel affect your training and performance? (please state)

27. Have you experienced irregular or missed periods for more than 3 months?

- Yes
- No
- Other (please provide further details)

28. If Yes, did this occur after experiencing concussion?

- Yes
- No
- Other (please provide further details)

29. Provide any further information you feel is relevant to training, performance and injuries in relation to your menstrual cycle:

30. Do you receive pre-season health and/or medical screening,cognitive testing/screening or baseline concussion testing e.g. SCAT5?

- Yes
- No
- Other (please provide further details)

31. If yes what did it include? (select all which apply)

- Baseline concussion testing
- Menstrual cycle/hormonal contraceptive history
- Fitness testing
- Injury history
- Other (please provide further details)

32. Do you have any further comments to make about women's rugby union training which you believe are important for future research?

Thank you!

The research team would like to sincerely thank you for your time and participation in this worldwide women's rugby union survey.

We believe that women athletes should be trained like women athletes, and not like they are just small men.

Please share with all the women rugby players you know, from anywhere, at any level! Keep an eye

out for our findings over the next six months by following **@TBI_ResearchNet** on Twitter. If you have any further enquiries please email Dr Elisabeth Williams: [redacted]

Appendix B. Survey Ethics Approval

APPLICATION FOR ETHICAL COMMITTEE APPROVAL OF A RESEARCH PROJECT

All research with human participants, or on data derived from research with human participants that is not publicly available, undertaken by staff or students linked with A-STEM or in the College of Engineering more widely must be approved by the College of Engineering Research Ethics Committee.

RESEARCH MAY ONLY COMMENCE ONCE ETHICAL APPROVAL HAS BEEN OBTAINED
Approval reference number is 2020-035 and the date of approval is 15/07/2020

The researcher(s) should complete the form in consultation with the project supervisor. After completing and signing the form students should ask their supervisor to sign it. The form should be submitted electronically to coe-researchethics@swansea.ac.uk.

Applicants will be informed of the Committee's decision via email to the project leader/supervisor.

1. TITLE OF PROJECT
Oceans 15: Building an Evidence Base for Women-Specific Training and Injury Identification in Rugby Union – Global Questionnaire

2. DATE OF PROJECT COMMENCEMENT AND PROPOSED DURATION OF THE STUDY
Commencement: July 2020, when ethical approval is granted. The questionnaire will be open for twelve weeks from commencement and the data generated will be used for up to three years to generate open source publications.

3. NAMES AND STATUS OF THE RESEARCH TEAM *State the names of all members of the research group including the supervisor(s). State the current status of the student(s) in the group i.e. Undergraduate, postgraduate, staff or other (please specify).*
Dr Elisabeth Williams, Senior Lecturer, ASTEM, College of Engineering, Swansea University, [redacted] Dr Anna Stodter, Senior Lecturer, Cambridge Centre for Sport and Exercise Science, Anglia Ruskin University, [redacted] Dr Izzy Moore, Senior Lecturer, School of Sport and Health Sciences, Cardiff Metropolitan University [redacted] Dr Genevieve Williams, Lecturer, Sport and Health Sciences, University of Exeter [redacted] Dr Olga Roldan-Reoyo, Research Fellow, ASTEM, College of Engineering, Swansea University, [redacted] Dr Natalie Brown, Research Fellow, ASTEM, College of Engineering, Swansea University [redacted] Ms Freja Petrie, PhD Candidate, ASTEM, College of Engineering, Swansea University [redacted] Dr Stacy Sims, Te Huataki Waiora - School of Health, The University of Waikato, New Zealand [redacted] Ms Joanna Perkins, Physiotherapist, Mumma Physio, Cardiff, [redacted]

Ms Lesley McBride, Senior Lecturer in Physiotherapy, Coventry University & RFU [redacted]
Ms Natalie Hardaker, Injury Prevention Specialist & PhD Candidate, New Zealand Accident Compensation Corporation (ACC), [redacted]
Ms Rebecca Cole, Undergraduate Student, Anglia Ruskin University, Cambridge, [redacted]

Ms Charley Keen, MSc Research Student, ASTEM, College of Engineering, Swansea University, [redacted]
Mr George Wells, MSc Research Student, ASTEM, College of Engineering, Swansea University, [redacted]
Mrs Nicole Fia, MSc Research Student, ASTEM, College of Engineering, Swansea University, [redacted]/[redacted]
Ms Tilly Russell, Sport Science Undergraduate Student, ASTEM, College of Engineering, Swansea University, [redacted]
Mr Elis Pryse, Sport Science Undergraduate Student, ASTEM, College of Engineering, Swansea University, [redacted]
Mr Will Robinson, Sport Science Undergraduate Student, ASTEM, College of Engineering, Swansea University, [redacted]
Mr Callum Jarvis, Sport Science Undergraduate Student, ASTEM, College of Engineering, Swansea University, [redacted]
Ms Holly Davies, Sport Science Undergraduate Student, ASTEM, College of Engineering, Swansea University, [redacted]
Mr Jack Shine, Sport Science Undergraduate Student, ASTEM, College of Engineering, Swansea University, [redacted]

4. RATIONALE AND REFERENCES

*Describe in **no more than 200 words** the background to the proposed project.*
In all sections below that detail your study and its aims please use language suitable for a lay audience.

Rugby union is a full contact team sport characterised by frequent collision events. Worldwide, women's participation in rugby is rising by 28% per year[1], with over 2.7 million women players registered with World Rugby in 2018 [1]. Meanwhile, professionalisation of women's rugby is still evolving 33 years after the male game. Rugby empowers women[2], encouraging a focus on increased fitness, confidence and strength rather than societal ideals[3]. Collision events inherent to the game are nevertheless responsible for a high incidence of injuries, including traumatic brain injuries[4]. There are widespread deficiencies in knowledge about such injuries amongst players and coaches.

Evidence shows women are 2.6 times more likely than men to suffer a concussion in sport[5,6,7]. Women athletes take longer to return to play than men, have a differing symptom burden [8] and are more likely to report dizziness, fatigue and difficulty concentrating [9,10]. Differences between male and female head/neck physiology [12,13] and neuronal structure [14] may cause this greater injury burden. Yet, most existing medical and sports science literature uses male participants, with generalisation of results to women [11] creating a significant gender data gap. The current research will begin to address this gap by using a survey to investigate the experiences of players and coaches in women's rugby union, creating an evidence base to inform targeted, women-specific interventions for improving player safety.

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11. Costello JT, Bieuzen F, Bleakley CM. Where are all the female participants in Sports and Exercise Medicine research? *Eur J Sport Sci*. 2014;14(8):847-851. doi:10.1080/17461391.2014.911354
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5. OBJECTIVES

State the objectives of the project, i.e. one or more precise statements of what the project is designed to achieve.

This research aims to collect information about the levels of understanding and experiences of players and coaches in women's rugby union regarding head injuries, concussion and training for injury prevention. The overarching objective is to bridge the significant gender data gap endemic in sport science and sports medicine, by creating a data-driven evidence base to develop targeted, women-specific interventions to improve player safety.

The project will utilise two questionnaires to survey a large number of women rugby players (aged 18 and over) and coaches of all levels of participation. The player's questionnaire will comprise three sections; the first of which will include basic anthropometric characteristics, playing position, playing level, career duration and basic concussion and women's health knowledge. The data gathered will serve as an evidence base for proposed training or match interventions specific to the women's game. A plethora of data has been published regarding male (particularly professional) anthropometrics for different playing positions, but no such data exists for women.

Section 2 includes more detailed questions regarding experiences of injury (particularly concussion), basic health understanding and health monitoring practices, as well as training and preparation for the collisions prevalent in rugby. Most male players began their rugby careers at an early age and progressed gradually to full contact alongside peers of an equal level. Women players in the UK may not have been presented with similar opportunities and many begin playing careers as adults starting university. Thus, one of the objectives of this section is to determine the level of preparedness for rugby collisions that women players are afforded prior to their first competitive matches. In some cases, novice players will compete against experienced national team members with a potentially dangerous gulf in the respective levels of ability.

Section 3 will explore injury prevalence and performance specifically in relation to the menstrual cycle. The menstrual cycle has been suggested to be a mediator of injury risk. The data gathered will inform the development of women-specific training practices which are relevant to rugby and highlight gaps in player knowledge relating to hormonal cycle awareness and relevant nutritional demands. Importantly, future studies will be focused on how the menstrual cycle affects the concussion injury burden. For such studies to succeed, it must first be established how much women athletes know about their bodies. If the use of smartphone apps to monitor their cycles, for example, is commonplace, then data collection regarding concussion severity at the different phases will be considerably easier to collect.

The coaches' survey follows a similar format and is designed to assess the knowledge and awareness of coaches of women's rugby teams regarding concussive injuries as well as training and performance implications of the menstrual cycle.

6.1 STUDY DESIGN Outline the chosen study design (e.g., cross-sectional, longitudinal, intervention, RCT, questionnaire etc)
Cross-sectional questionnaires (one for players and a separate questionnaire for coaches).

6.2. STUDY DESIGN

- state the number and characteristics of study participants
- state the inclusion criteria for participants
- state the exclusion criteria for participants and identify any requirements for health screening
- state whether the study will involve vulnerable populations (i.e. young, elderly, clinical etc.)
- state the requirements/commitments expected of the participants (e.g. time, exertion level etc)

The player questionnaire will be advertised to all women rugby players over the age of 18 worldwide, via national federations, women's rugby groups and relevant social media platforms. There will be no upper limit to the numbers included and it is anticipated that the minimum number of respondents will be 1000. The characteristics of these study participants will be women's rugby union players who are currently registered, or have been in the past five years, with any rugby union (15's and 7's) club, university and/or those who regularly partake in rugby games at local, university, elite, professional and/or national level.

The coaches' questionnaire will likewise be advertised to any person, of any gender/sex, who is currently (or who has been in the past five years) involved in a coaching role in women's rugby union at any level.

Inclusion criteria for the player questionnaire: women's rugby union players aged 18 years and over, registered with any club, university or relevant organisation, who regularly compete in rugby union games (15's and 7's) at local, university, elite, professional and/or international level, in any World Rugby Tier 1 country.

Inclusion criteria for the coach questionnaire: currently involved in coaching of a women's rugby union team at local, university, elite, professional and/or international level, in any country. Participants can include coaching or managerial roles who are involved in the organisation and scheduling of training, including strength and conditioning programming.

Exclusion criteria for the player questionnaire: any individual who is under the age of 18 and is not currently (or not in the past five years) registered as a women's rugby player with any club at local, university, elite, professional and/or international level, in any country.

Exclusion criteria for the coach questionnaire: any individual who is under the age of 18 and who has not been in a coaching or managerial role for women's rugby players with any club at local, university, elite, professional and/or international level, in any World Rugby Tier 1 country, within the last five years.

There is no requirement for health screening as this study involves an online, anonymous internet survey. This study

does not involve any vulnerable populations and no one under the age of 18.

The requirements of this study will be to complete an anonymous, online questionnaire, with a total of 124 questions, with each participant completing approximately 80. The estimated time to complete this will be approximately 40 minutes to an hour. Participants will be given the option of providing their email address to the research team, should they wish to be involved in any future studies about women's rugby union. The email addresses provided will not be linked to their survey responses.

6.3. PARTICIPANT RECRUITMENT *How and where will participants be recruited? How will you ensure that these methods of recruitment do not compromise the ability of the research participant to freely consent to and withdraw from the study?*
The player questionnaire will be advertised to women rugby players over the age of 18 worldwide, via women's rugby groups on social media platforms. We will leverage social media platforms (Facebook, Twitter) for recruitment, using snowball sampling. (Gelinas, L., Pierce, R., Winkler, S., Cohen, I. G., Lynch, H. F., & Bierer, B. E. (2017). Using Social Media as a Research Recruitment Tool: Ethical Issues and Recommendations. *The American journal of bioethics: AJOB*, *17*(3), 3–14. https://doi.org/10.1080/15265161.2016.1276644) The coaches' questionnaire will be advertised to coaches of women's rugby over the age of 18 worldwide, via women's rugby coaching and general rugby coaching groups on social media platforms. The questionnaire links will be posted on these platforms in the form of a flyer. When participants log-on to the JISC survey page they will be provided with a covering information sheet. **They cannot move onto the survey before checking a box that states that they have read and understand this information; including that their answers will be, and will remain, anonymous, thus there will be no ability to withdraw answers upon completion and submission of the survey.** By accepting this information, it signals that they consent to doing the survey. If, after reading the online information sheet, they have any questions they will be invited to contact one of the principal investigators to have their questions answered. Information for contacting the principal investigators will be provided online.

6.4 DATA COLLECTION METHODS *- describe all of the data collection/experimental procedures to be undertaken* *- state any dietary supplementation that will be given to participants and provide full details in Section 6.5* *- state the inclusion of participant information and consent forms (and assent forms where necessary in appendices)* *- Where you are asking research participants to undertake physical activity consider appropriate health screening processes. Note that the ACSM have updated their guidelines in a consensus statement dated 2015.*
All data will be collected in the form of an anonymous, online questionnaire via the platform JISC. No experimental procedures or interventions are involved in this study. No dietary supplementation is included in this study. The participant information sheet is attached to this application document along with a click to consent option which will direct participants to the survey. No participants will be asked to undertake physical activity as part of this study.

6.5 DATA ANALYSIS TECHNIQUES *- describe briefly the techniques that will be used to analyse the data*
A number of quantitative and qualitative analysis methods and tools will be employed in the evaluation of these data. Comparison and correlative tests, multivariate analyses and where appropriate (and

pending the number of responses received), more sophisticated big data analysis methods will be employed to generate actionable insights from this very unique and valuable dataset.

6.6. STORAGE AND DISPOSAL OF DATA AND SAMPLES *-describe the procedures to be undertaken for the storage and disposal of data and samples* *- identify the people who will have the responsibility for the storage and disposal of data and samples* *- identify the people who will have access to the data and samples* *- state the period for which the raw data will be retained on study completion (normally 5 years, or end of award. But data should not be retained for longer than is necessary for the purposes of the research project.)* *- Please confirm that where data is being stored away from Swansea University (for example on cloud based services) that procedures are still in line with GDPR legislation.*
All data will be stored on Swansea University's JISC cloud-based system, accessible by those named in Section 3 for the duration they survey is active (3 months). Data will be securely stored on the secure Swansea University cloud-based system for a further three-year period during which these data will be actively utilised. After this time, the data will be stored on an encrypted hard drive by the principal investigator (EW) for up to seven years after data collection. No data will contain any identifiable features or characteristics unique to any individual. Any email addresses volunteered by research participants indicating interest in future studies of this nature, will be held by members of the research team on their respective secure email servers, not attached to any information provided in this questionnaire.

6.7 HOW DO YOU PROPOSE TO ENSURE PARTICIPANT CONFIDENTIALITY AND ANONYMITY?
Participant consent will be in the form of a click to consent button and no names or any identifying characteristics will be recorded.

7. LOCATION OF THE PREMISES WHERE THE RESEARCH WILL BE CONDUCTED. *- list the location(s) where the data collection and analysis will be carried out* *- identify the person who will be present to supervise the research at that location* *- If a first aider is relevant, please specify the first aider and confirm that they possess the first aid qualifications appropriate for this form of research*
There is no required physical location. The online questionnaire is expected to be completed where the participant is comfortable at answering (e.g. at home). There will be no member of the research team present to supervise the questionnaire completion, however, the contact details of the research team will be made available to all questionnaire respondents, in the case they have any queries when completing the questionnaire.

8. POTENTIAL PARTICIPANT RISKS AND DISCOMFORTS *- identify any potential physical risk or discomfort that participants might experience as a result of participation in the study.* *- identify any potential psychological risk or discomfort that participants might experience as a result of participation in the study.* *- Identify the referral process/care pathway if any untoward events occur*

Participants will have approximately 30 minutes of their time inconvenienced by the completion of this survey. No physical risk or discomfort will be imposed on participants other than those required to operate a computer or smartphone.

Due to the anonymity of the survey, specific identification of participants with medical risk factors is not feasible. In the event that a participant has had a previous traumatic brain injury through participation in sport or any other untoward life event, there is a small potential for some questions to trigger difficult memories. The nature of the questionnaire is designed to learn about the mechanisms of these injurious events, to develop processes and infrastructure to minimise the risk of recurrence in the future. It is hoped that participants will view this exercise as a positive step in improving the safety of their sport for women, and as such, will respond favourably. The participant information sheet will include the contact details of the research team members, who participants are welcome to contact for a confidential conversation. Participants are also advised to speak with someone they trust, in the event they become upset by any of the questions.

9.1. HOW WILL INFORMED CONSENT BE SOUGHT? *Will any organisations be used to access the sample population?* *Will parental/coach/teacher consent be required? If so, please specify which and how this will be obtained and recorded?*
Social media platforms will be used to access the sample population. A flyer displaying basic information about the study will be posted on women's rugby forums, containing an open invitation to participate. When participants log-on to the JISC survey page they will be provided with a covering information sheet. **They cannot move onto the survey before checking a box that states that they have read and understand this information; including that their answers will be, and will remain, anonymous, thus there will be no ability to withdraw answers upon completion and submission of the survey.** By accepting this information, it signals that they consent to doing the survey. If, after reading the online information sheet, they have any questions they will be invited to contact one of the principal investigators to have their questions answered. Information for contacting the principal investigators will be provided online. All survey respondents will be over the age of 18 so no parental/coach/teacher consent will be required.

9.2 INFORMATION SHEETS AND CONSENT/ASSENT FORMS **Please ensure that your forms are written in clear, simple language enabling research participants to fully understand the project.**
• Have you included a participant information sheet for the participants of the study? YES/ • Have you included a parental/guardian information sheet for the parents/guardians of the study? N/A • Have you included a participant consent (or assent) form for the participants in the study? YES • Have you included a parental/guardian consent form for the participants of the study? N/A

10. IF YOUR PROPOSED RESEARCH IS WITH VULNERABLE POPULATIONS (E.G., CHILDREN), HAS AN UP-TO-DATE DISCLOSURE AND BARRING SERVICE (DBS) CHECK (PREVIOUSLY CRB) IF UK, OR EQUIVALENT NON-UK, CLEARANCE BEEN REQUESTED AND/OR OBTAINED FOR ALL RELEVANT RESEARCHERS?.
If appropriate please provide a list below including the name of the researcher and confirming that they have an up to date DBS check. Please also confirm the type of check (i.e. basic/enhanced). NO

11. HUMAN TISSUE ACT **Does your research involve the collection or storage of human tissue samples?** **Where not relevant please respond N/A. Where appropriate please provide further details.** Please note that University ethics committee approval is not sufficient to comply with legislation for the storage of relevant material for research.
N/A

12. STUDENT DECLARATION

Please read the following declarations carefully and provide details below of any ways in which your project deviates from these. Having done this, each student listed in section 2 is required to sign where indicated.

- ***"I have ensured that there will be no active deception of participants.***
- ***I have ensured that no data will be personally identifiable.***
- ***I have ensured that no participant should suffer any undue physical or psychological discomfort (unless specified and justified in methodology).***
- ***I certify that there will be no administration of potentially harmful drugs, medicines or foodstuffs.***
- ***I will obtain written permission from an appropriate authority before recruiting members of any outside institution as participants.***
- ***I certify that the participants will not experience any potentially unpleasant stimulation or deprivation.***
- ***I certify that any ethical considerations raised by this proposal have been discussed in detail with my supervisor.***
- ***I certify that the above statements are true with the following exception(s):***

Student/Researcher signature: (include a signature for each student in research team)
Date:

Where submitted electronically we will accept the lead supervisor/researcher's email of the

application as confirmation that both they and other researchers on the project have discussed and are happy to adhere to the above.

13. SUPERVISOR [redacted]

Date: 26/06/2020

Amendment 1 (adding student names) 12/10/2020 [redacted]

PARTICIPANT INFORMATION SHEET - PLAYERS

(Version 1.1, Date: 29 /06/2020)

Project Title:

Oceans 15: Building an Evidence Base for Women-Specific Training and Concussion Identification in Rugby Union – Global Questionnaire

Contact Details:

Dr Elisabeth Williams
[redacted]
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Dr Anna Stodter - [redacted]
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Dr Genevieve Williams - [redacted]
Dr Olga Roldan-Reoyo - [redacted]
Dr Natalie Brown - [redacted]
Freja Petrie - [redacted]
Dr Stacy Sims - [redacted]
Joanna Perkins - [redacted]
Lesley McBride - [redacted]
Natalie Hardaker - [redacted]

1. Invitation Paragraph

My name is Dr Elisabeth Williams and I am a senior lecturer in applied biomechanics at Swansea University in Wales, U.K. On behalf of the research team listed above, we would like to thank you for your time and interest in completing this questionnaire.

2. What is the purpose of the study?

The aim of this survey questionnaire is to gather data about women rugby players who participate at all levels; local club, university, elite, professional and international. You will be aware that professionalisation of women's rugby has come 33 years after the male game. Currently, worldwide women's participation in rugby is rising by 28% per year, with 2.7 million registered players at the end of 2018. As rugby has historically been a male-dominated sport, most research about training techniques and injury risk has focussed on male athletes.

Male-based findings in sports and medicine are routinely generalised to women, even when there is little to no evidence about how women respond. This has created a significant gender data gap, and training programs are a good example of this. What this ultimately means is 'women are not small men' and we need to ensure we are training women appropriately to make them better, safer athletes. This very much applies to sports related mild traumatic brain injury (mTBI), which is a serious problem in contact sports like rugby.

There are many physical differences between males and females, in addition to playing opportunities and access to expert coaching, which may compromise the safety and performance of women rugby players. Reports have shown women to be 2.6 times more likely to suffer a concussion in sport. Research shows that women athletes take longer to return to play, have worse symptoms and are more likely to report dizziness, fatigue and difficulty concentrating than males. Differences between male and female head/neck physiology, neck strength and neuronal structure in the brain have been linked to a greater head injury severity in women following rugby impacts.

3. Why have I been chosen?

You have been approached via your national rugby federation and/or women's rugby social media platforms to participate in this study as you are a woman rugby player, over the age of 18. We would like to know about your experiences, the anthropometrics of different playing positions, injury patterns and health monitoring practices in particular. The data you provide will help us to create an evidence base to develop targeted, women-specific interventions to improve player safety. We hope to have as many women's rugby players as possible complete this survey in order to build a valuable and informative dataset that we can all benefit from.

Taking part in this study is entirely voluntary. The questionnaire responses are completely anonymous, even to the research team. **As your responses for each question are automatically saved when you answer them, and no identifiable information is recorded in this study, we are unable to withdraw your data once you have provided a response.**

4. What will happen to me if I take part?

Participation in this study involves completing the anonymous questionnaire which follows this document, after you click to confirm that you are over 18, fit the criteria for the study and agree to participate. The questionnaire is in three sections:

- **Section One:** Demographics, playing experience and positions, playing level and basic health information.
- **Section Two:** Concussion history, strength and conditioning, injury prevention training and injury management.
- **Section Three:** Women-specific concussion symptoms, the effects of menstrual cycle on training, performance and injuries, female physiology, medical support and financial resources in women's rugby union.

The questionnaire should take you approximately 20-30 minutes for each section. By answering all the sections of the questionnaire, you will help us to tackle the gender data gap.

5. What are the possible disadvantages of taking part?

Some questions will ask you about previous concussions or possible concussions you may have had, both while playing rugby and in other aspects of your life. This may trigger upsetting memories, depending on the circumstances surrounding your injuries. If you do feel upset by any content in the questionnaire, you are advised to contact someone you trust and you are always welcome to contact anyone from the research team, whose email addresses are provided above.

6. What are the possible benefits of taking part?

By taking part in this study, you will be making an invaluable contribution to the much-needed knowledge about women's rugby union. This information will be used to improve training strategies to minimise the risk of brain injury to women rugby players and other contact sport athletes. The data gathered from this questionnaire will also help us understand what most women rugby players know about how their bodies respond to trauma and to different training stimuli at different phases of the menstrual cycle. With that information we can work with rugby organisations to improve training practices and guidelines specific to women athletes. In addition to publishing our generalised findings in open-source journals, we will be making our generalised findings available on Twitter: *(insert Twitter handle).*

7**. Will my taking part in the study be kept confidential?**

Due to the nature of this anonymous survey, your identity will not be recorded. The anonymised data will be kept by the research team and used both directly in publishable studies and as pilot information for three years. After this date, the data will be stored for a further four years for reference for future work in this area. All anonymised data will be kept on a secure cloud platform, accessible only by the research team.

Here is a news article link from early 2020 to provide you with more context for this study:
https://www-bbc-co-uk.cdn.ampproject.org/c/s/www.bbc.co.uk/news/amp/uk-wales-51434749

Data Protection and Confidentiality
Your data will be processed in accordance with the Data Protection Act 2018 and the General Data Protection Regulation 2016 (GDPR). All information collected about you will be kept strictly confidential. Your data will only be viewed by the researcher/research team.

All electronic data will be stored on a password-protected computer file at Swansea University. Your consent information does not require your name to eliminate risk in the event of a data breach.

Please note that as data is being collected online, once the data has been submitted online you will be unable to withdraw your information.

Data Protection Privacy Notice
The data controller for this project will be Swansea University. The University Data Protection Officer provides oversight of university activities involving the processing of personal data, and can be contacted at the Vice Chancellors Office.

Your personal data will be processed for the purposes outlined in this information sheet.
Standard ethical procedures will involve you providing your consent to participate in this study by completing the consent form that has been provided to you.

The legal basis that we will rely on to process your personal data will be necessary for the performance of a task carried out in the public interest. This public interest justification is approved by the College of Engineering Research Ethics Committee, Swansea University.

The legal basis that we will rely on to process special categories of data will be processing is necessary for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes.

How long will your information be held?
We will hold any personal data and special categories of data for seven years.

What are your rights?
Please visit the University Data Protection webpages for further information in relation to your rights.

Any requests or objections should be made in writing to the University Data Protection Officer:-

University Compliance Officer (FOI/DP)
Vice-Chancellor's Office
Swansea University
Singleton Park
Swansea
SA2 8PP
Email: dataprotection@swansea.ac.uk

How to make a complaint
If you are unhappy with the way in which your personal data has been processed, you may in the first instance contact the University Data Protection Officer using the contact details above.

If you remain dissatisfied, then you have the right to apply directly to the Information Commissioner for a decision. The Information Commissioner can be contacted at: -

Information Commissioner's Office,
Wycliffe House,

Water Lane,
Wilmslow,
Cheshire,
SK9 5AF
www.ico.org.uk

8. What if I have any questions?

Re-iterate that further information can be obtained from the researcher contact stated above. Also state that the project has been approved by the College of Engineering Research Ethics Committee at Swansea University. If you have any questions regarding this, any complaint, or concerns about the ethics of this research please contact Dr Andrew Bloodworth, Chair of the College of Engineering Research Ethics Committee, Swansea University [redacted] The institutional contact for reporting cases of research conduct is Registrar & Chief Operating Officer Mr Andrew Rhodes. Email: researchmisconduct@swansea.ac.uk. Further details are available at the Swansea University webpages

PARTICIPANT CONSENT FORM
(Version 1.1, Date: 29/06/2020)

I confirm that I have read and understood the information sheet dated 29/06/2020, version number 1.1 and that I have the opportunity to contact members of the research team to ask questions.	☐
I understand that my participation is voluntary, and the questionnaire responses are completely anonymous, even to the research team.	☐
I understand that my responses for each question are automatically saved when I answer them, and no identifiable information is recorded in this study. I understand that I am unable to withdraw my data once I have provided a response.	☐
I understand that data obtained may be looked at by responsible individuals from Swansea University or from regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to these records.	☐
I understand that data I provide may be used in reports and academic publications in anonymous fashion.	☐
I agree to take part in the above study.	☐

PARTICIPANT INFORMATION SHEET - COACHES

(Version 1.1, Date: 29 /06/2020)

Project Title:

Oceans 15: Building an Evidence Base for Women-Specific Training and Injury Identification in Rugby Union – Global Questionnaire

Contact Details:

Dr Elisabeth Williams
[redacted]
Bay Campus, Swansea University
Fabian Way
Swansea, SA18EN United Kingdom
[redacted]

Dr Anna Stodter - [redacted]
Dr Izzy Moore - [redacted]
Dr Genevieve Williams - [redacted]
Dr Olga Roldan-Reoyo - [redacted]
Dr Natalie Brown - [redacted]
Freja Petrie - [redacted]
Dr Stacy Sims [redacted]
Joanna Perkins - [redacted]
Lesley McBride - [redacted]
Natalie Hardaker - [redacted]

2. Invitation Paragraph

My name is Dr Elisabeth Williams and I am a senior lecturer in applied biomechanics at Swansea University in Wales, U.K. On behalf of the research team listed above, we would like to thank you for your time and interest in completing this questionnaire.

2. What is the purpose of the study?

The aim of this survey questionnaire is to gather data about the sport of women's rugby players at all levels; local club, university, elite, professional and international. You will be aware that professionalisation of women's rugby has come 33 years after the male game. Currently, worldwide women's participation in rugby is rising by 28% per year, with 2.7 million registered players at the end of 2018. As rugby has historically been a male-dominated sport, most research about training techniques and injury risk has focussed on male athletes.

The following has motivated us to carry out this project:

- Male-based findings in sports and medicine are routinely generalised to women, even when there is little to no evidence about how women respond. This has created a significant gender data gap
- What this ultimately means is 'women are not small men' and we need to ensure we are training women appropriately to make them better, safer athletes. This very much applies to sports related mild traumatic brain injury (mTBI), which is a serious problem in contact sports like rugby
- There are many physical differences between males and s, in addition to playing opportunities and access to expert coaching, which may compromise the safety and performance of women rugby players
- Reports have shown women to be 2.6 times more likely to suffer a concussion than men.
- Research shows that women athletes take longer to return to play, have worse symptoms and are more likely to report dizziness, fatigue and difficulty concentrating than males
- Differences between male and female head/neck physiology, neck strength and neuronal structure in the brain have been linked to a greater head injury severity in women following rugby impacts

3. Why have I been chosen?

You have been approached via women's rugby organisations and social media platforms to participate in this study as you are involved in coaching women's rugby players and you are over the age of 18. We would like to know about your experiences, the anthropometrics of different playing positions, injury

patterns and health monitoring practices in particular. The data you provide will help us to create an evidence base to develop targeted, women-specific interventions to improve player safety. We hope to have as many women rugby players and coaches as possible complete this survey in order to build a valuable and informative dataset that we can all benefit from.
Taking part in this study is entirely voluntary. The questionnaire responses are completely anonymous, even to the research team. **As your responses for each question are automatically saved when you answer them, and no identifiable information is recorded in this study, we are unable to withdraw your data once you have provided a response.**

4. What will happen to me if I take part?

Participation in this study involves completing the anonymous questionnaire which follows this document, after you click to confirm that you are over 18 and fit the criteria for the study. The questionnaire is in three sections;

- **Section One:** Demographics, playing experience and positions, playing level and basic health information
- **Section Two:** Concussion history, strength and conditioning, injury prevention training and injury management.
- **Section Three:** Women-specific concussion symptoms, female physiology including awareness of the effects of menstrual cycle on training, performance and injury risk. Questions regarding athlete medical support and financial resources in women's rugby union. This section will also ask you about possible support for a women-specific training curriculum pre-contact for players new to the sport.

The questionnaire should take you approximately ten minutes for section 1 and depending on the length of your answers, 15-20 minutes each for sections 2 and 3.

5. What are the possible disadvantages of taking part?

Some questions will ask you about previous concussions or possible concussions you may have witnessed. This may trigger upsetting memories, depending on the circumstances surrounding your injuries. If you do feel upset by any content in the questionnaire, you are advised to contact someone you trust and you are always welcome to contact anyone from the research team, whose email addresses are provided above.

6. What are the possible benefits of taking part?

By taking part in this study, you will be making an invaluable contribution to the much-needed knowledge about women's rugby union. This information will be used to improve training strategies to minimise the risk of brain injury to women rugby players and other contact sport athletes. The data gathered from this questionnaire will also help us understand what most women rugby players and coaches know about how women's bodies respond to trauma. It will also help us gauge the extent to which players and coaches understand and use the menstrual cycle as a training aid. With that information we can work with rugby organisations to improve training practices and guidelines specific to women athletes. In addition to publishing our generalised findings in open-source journals, we will be making our generalised findings available on Twitter: *(insert Twitter handle)*

7. Will my taking part in the study be kept confidential?

Due to the nature of this anonymous survey, your identity will not be recorded. The anonymised data will be kept by the research team and used both directly in publishable studies and as pilot information for three years. After this date, the data will be stored for a further four years for reference for future work in this area. All anonymised data will be kept on a secure cloud platform, accessible only by the research team.

Here is a link to a news article from early 2020 to provide you with more context for this study:

https://www-bbc-co-uk.cdn.ampproject.org/c/s/www.bbc.co.uk/news/amp/uk-wales-51434749

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Swansea University
Singleton Park
Swansea
SA2 8PP
Email: dataprotection@swansea.ac.uk

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Information Commissioner's Office,
Wycliffe House,

Water Lane,
Wilmslow,
Cheshire,
SK9 5AF
www.ico.org.uk

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I understand that data I provide may be used in reports and academic publications in anonymous fashion.	☐
I agree to take part in the above study.	☐