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Match Events Associated With Injury In Schools Rugby Union

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MATCH EVENTS ASSOCIATED WITH INJURY IN SCHOOLS RUGBY UNION

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ABSTRACT

Rugby union is one of the most popular sports played within English schools, but there have been concerns about the high-impact, contact nature of the game and potential risk of injury. Despite this, very little is known about the nature of these injuries or the matches and events in which they are caused.

It is widely accepted that injury incidence increases with age, yet the youth population is often treated as a whole. The first study in this thesis, chapter four, describes and compares the incidence, severity and burden of schoolboy rugby injuries within the under-13, under-15 and under-18 age groups. It highlights the high injury incidence and burden at under-18 and draws attention to the large proportion of injuries sustained within the tackle and resulting in concussion at all age groups. To add context to the first study and investigate the events causing injury, chapter five utilises match analysis to describe the events occurring within games at different age groups and to identify those which are of the greatest concern. Accidental collisions were found to pose the greatest risk to players. The tackle was found to be the most common contact event and carried the second highest risk of injury. Finally, chapter six examines the characteristics of the tackle at each age group and identifies associations between these characteristics and head contact. This chapter concludes that tacklers have head contact more often than ball carriers, that under-13 tacklers have a higher likelihood of head contact than older tacklers and that the likelihood of head contact is higher when tackling from the front, whilst static and when there is more than one tackler.

This is the first body of work to investigate schoolboy rugby injuries and the events associated with them, for comparison across age groups, in an English schoolboy setting. This thesis makes numerous recommendations for law changes, identifies topics for future research and provides a foundation for which age-specific injury prevention strategies can be developed, which are based on both the injuries and events occurring within the game.

PUBLICATIONS

ABSTRACTS

Hancock, M., Roberts, S., Barden, C., McKay, C., Kemp, S., & Stokes, K. (2020) Epidemiology of injury in English schoolboy Rugby Union. *British Journal of Sports Medicine (Monaco Abstracts).* doi: 10.1136/bjsports-2021-IOC.7.

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Hancock, M., Barden, C., Stokes, K., Roberts, S., McKay, C., Kemp, S., & Faull-Brown, R. (2020) *Youth Rugby Injury Surveillance Project Season Report 2018/19*. Available from: https://www.englandrugby.com/participation/playing/player-welfare-rugby-safe/rugbysafe-research.

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Early on, Dr Madi Davies informed me that my thesis was only the final step and that a PhD was really the years of learning, relationship-building, problem solving and hard work that preceded it. At the time I didn’t really know what she meant, but I do now. I have often bothered her with questions, both practical and philosophical, and she has always taken the time to help and offer guidance, no matter how busy she has been. Truly, thank you.

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Celer et Audax.

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CHAPTER ONE

AN INTRODUCTION

1.1 Research Context

Rugby union is one of the most popular sports in the world, with an estimated 9.6 million people playing (3.5 million registered, 6.1 million non-registered) across 123 countries (World Rugby, 2018). During a match, which is characterised by intermittent bouts of high intensity running and contact events (Roberts, Trewartha, Higgitt, El-Abd and Stokes, 2008), each team competes to gain control of a ball and get it across the opposition team's "try line" in order to gain points and ultimately win the game.

There are two codes of rugby: league and union. Both codes are played for 80 minutes and share many similarities, including their origin, but are two distinct sports. One of the key differences are the laws of possession, as in rugby league there is a limit of six tackles before the ball must be handed to the opposition, the ball cannot be contested on the ground following a tackle and possession is contested using a scrum after going into touch, rather than a lineout. The size of the pitch, number of substitutions allowed and scoring also differs. Rugby union (hereafter referred to as 'rugby'), the focus of this thesis, is further broken down into two types of game: fifteen-a-side and seven-a-side. The seven-a-side game, often referred to as "rugby sevens" or "sevens", is played on the same size pitch as the fifteen-a-side game, but is generally played as part of a tournament, with fewer players and for a shorter period (seven minute halves), resulting in a faster game (Harrison, 2018). Whilst rugby sevens has become increasingly popular since becoming an Olympic sport in 2008, the fifteen-a-side game remains the most commonly played worldwide (Cruz-Ferreira, Cruz-Ferreira, Santiago and Taborda Barata, 2017).

The sport is thought to have originated from the public school system in England during the 1800's and is one of the most popular sports in England today, with almost 180,000 players aged 14-25 participating at least once per week (Sport England, 2016). Whilst it is widely played within the English school system, there has been concern among parents and health professionals due to the high-impact, contact nature of the game and potential risk of injury (Freitag, Kirkwood, Scharer, Ofori-Asenso and Pollock, 2015b; Carter, 2015; Archbold et al., 2017). The English school system largely consists of two types of school:

state and independent. State schools are funded by the British government and are more numerous (n=3456) than independent schools (n=2331) (Education Statistics Service, 2020). Independent schools are privately funded and, in the context of sport, often have greater resources at their disposal, such as coaching and medical staff, than state schools. Despite this, both state and independent schools often compete against each other and are treated as a single schoolboy population within this thesis.

Within schoolboy rugby, the specific laws, size of the pitch, length of the game and number of players are dependent on the age group (table 1.1). In England, the age-grade rugby system aims to ensure that players are able to enjoy rugby in a safe environment, where they can develop their running and catching skills before contact and more complex events are gradually introduced (England Rugby, 2021a). Under-13 (U13) is the youngest age group within secondary schools, playing for 50 minutes, with 13 players (six forwards, seven backs) and on a pitch no larger than 90x60 metres. They do not conduct lineouts, nor do they kick at goal. At under-15 (U15), games are played with a full team of 15 players (eight forwards, seven backs) and on a full size pitch (maximum 100x70 metres). Eight-player scrums (rather than six at U13), uncontested lineouts and kicking at goal are introduced and the length of the game is increased to 60 minutes. By under-18 (U18), the laws are similar to the adult game, but matches are only played for 70 minutes. The clock is not permitted to stop for breaks in play at any age group.

Table 1.1: Age-grade rugby progressions for the under-13, under-15 and under-18 age groups (England Rugby, 2021a).

	Under-13	**Under-15**	**Under-18**
Maximum Players, n	13	15	15
Maximum Pitch Size, metres	90x60	100x70	100x70
Maximum Time / Half, minutes	25	30	35
Additional Laws	6-Player Scrum Kicking	8-Player Scrum (U14) Kicking At Goal (U14) Uncontested Lineout, With Lift	Contested Lineout (U16)

Note: If not at the age group being described, the age group at which a law is introduced is stated in brackets.

Whilst injury is always going to be a concern within sport, especially in a youth setting (Abernethy and MacAuley, 2003), it is important that children and adolescents are not denied the opportunity to take part in games and physical activity; the benefits of which are widely accepted. Physically, this allows children to develop movement skills, improve physical fitness and to maintain a healthy weight, which is something of increasing concern in the United Kingdom (UK) (Janssen and Leblanc, 2010; Roca, 2019). Socially, taking part in sport can improve an individual's confidence, ability to work as part of a team and social skills (Salmon, 2001; Bailey, 2013). The reality is that most children will not become professional athletes, but these physical and social benefits and skills have the potential to build a strong foundation for later life.

It is important that the risk of injury in youth sport is understood to enable players and their parents to be able to make informed decisions about their participation within a particular activity and so that specific risk factors can be identified and addressed. If we wish to prevent injury, thus maximising participation, and improve player welfare, van Mechelen, Hlobil and Kemper (1992) suggested that there are four key stages (figure 1.1). The first of these is establishing the extent of the injury problem, by understanding how often injuries occur and how severe they are. The second phase involves establishing the aetiology and mechanisms of sports injuries to determine where the focus of an intervention should be. The third phase is where a preventative measure, based on the findings from the first two phases, is introduced to a population. The effectiveness of this intervention is then constantly assessed, with the findings being fed back into the first step, with the overarching aim of improving the intervention and further reducing injury risk. In order to begin this process, the incidence, severity, aetiology and mechanisms of injury must be understood within a given population or sport.

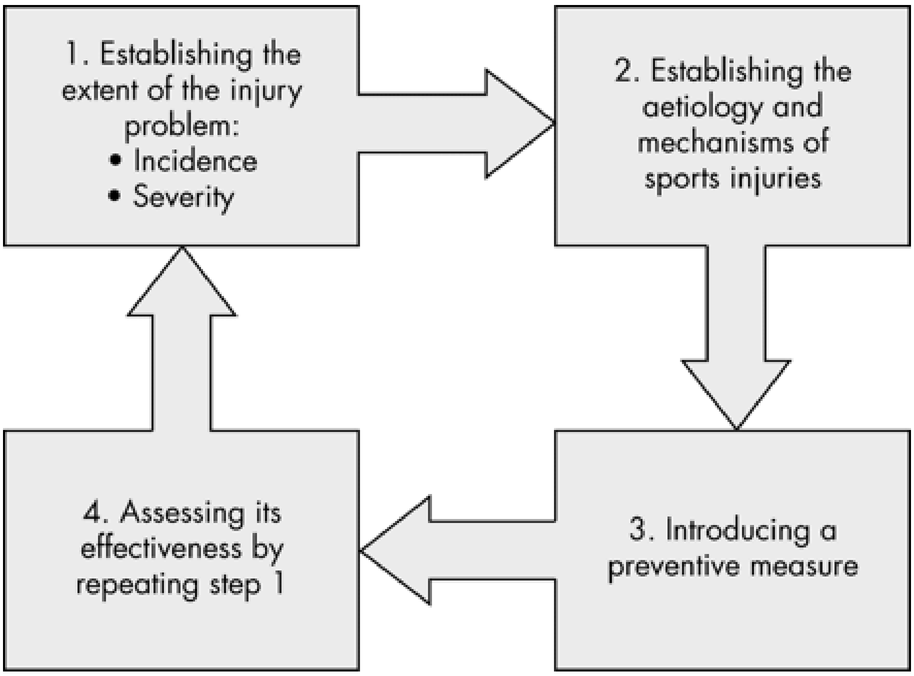

Figure 1.1: "The sequence of prevention" of sports injuries (van Mechelen et al., 1992).

Numerous injury epidemiological studies have been carried out in professional rugby, but as injury incidence in schoolboy rugby is lower than that of academy, amateur and professional rugby (Leahy et al., 2019), it would not be appropriate to use findings from research into these populations to inform decisions on injury prevention strategies for a schoolboy population. Just as data from other populations should not be applied to a youth setting, the youth population should not be treated as a whole as it is widely accepted that injury risk differs with age (Haseler, Carmont and England, 2010; Bleakley, Tully and O'Connor, 2011). Differences between age groups have been investigated in other countries but different societal factors, playing conditions and methodologies make drawing conclusions and making comparisons challenging (Bleakley et al., 2011; Leahy et al., 2019; Sewry et al., 2018). The epidemiology of rugby injuries within the English school system has been investigated, but the focus has been on different levels of competition, academy rugby compared to school rugby for instance, within similar age groups, rather than different age groups (Palmer-Green et al., 2013; Barden and Stokes, 2018). This thesis will build on the existing literature to develop the understanding of youth rugby injuries in England.

What is common across all levels of the game is that contact events are responsible for the most match injuries (Fuller, Taylor and Raftery, 2018; Roberts, Trewartha, England, Shaddick and Stokes, 2013; Bleakley et al., 2011; Viviers, Viljoen and Derman, 2018), however the number of injuries sustained are influenced by both the quantity of events that a player is exposed to and the likelihood that a specific event will cause injury (propensity). Both the number of events and their propensity to cause injury have been investigated at the men’s professional (Fuller, Brooks, Cancea, Hall and Kemp, 2007a) and community (Roberts, Trewartha, England and Stokes, 2015) levels, but not within schoolboy rugby. This can be done through video analysis (otherwise known as match analysis), a means to examine the actions performed during a match. This is useful as it allows for often dynamic and complex situations to be quantified (den Hollander, Jones, Lambert and Hendricks, 2018), adding context to injury epidemiological data, helping us to understand the demands of the game and highlighting events which pose the greatest risk to players.

Consistently, the tackle has been shown to be the most common match event and the one associated with the most injuries in youth rugby (Burger, Lambert and Hendricks, 2020). It is, therefore, an important event which needs to be understood if the game is to be made safer. It is widely accepted that poor tackle technique leads to a higher risk of injury (Burger et al., 2016; Davidow et al., 2018), but the characteristics of tackles within English schoolboy rugby have not been investigated. Much like the research into injury and match events, that characteristics of youth rugby tackles have been investigated in other settings (Burger et al., 2020), but research has not compared the characteristics of tackles at different age groups and has used varying definitions and methodologies. As such a key event, recommendations on tackle training and law changes should be specific to each age group, as one size is likely not to fit all.

This thesis investigates and explores the relationship between the epidemiology of injuries, match events and tackle characteristics within an English schoolboy population. Throughout, it seeks to describe the differences between the U13, U15 and U18 age groups, addressing phase one and two of van Mechelen's sequence of prevention and laying the foundation for future efforts to create age-specific injury prevention strategies.

1.2 Research Questions

This thesis will address the following research questions:

(1) What is the incidence, severity and burden of injuries within English schoolboy rugby and does this differ between age groups?

(2) What is the frequency of match events in schoolboy rugby matches and does this differ between age groups?

(3) What is the propensity for injury for different contact events and does this differ between age groups?

(4) What are the characteristics of the tackle at different age groups?

(5) Which characteristics of the tackle are associated with increased head contact and does this differ between age groups?

1.3 Thesis Outline

1.3.1 Chapter Two: A Review of the Literature

Chapter two will describe sports injury research and explore the current literature surrounding youth rugby injuries and the risk factors associated with them. It will also explore the use of match analysis to investigate match events and their association to injury, providing a contextual background for the subsequent work within this thesis.

1.3.2 Chapter Three: General Methodologies

Chapter three will outline the general methods that are used throughout this thesis. This chapter focuses on the participants, how they were recruited and how the data collection was conducted, before describing the definitions which were used throughout chapters four, five and six.

1.3.3 Chapter Four: Epidemiology of Injuries in English Schoolboy Rugby Union

Chapter four will investigate the epidemiology of injuries within English schoolboy rugby. It will describe the incidence, severity and burden of injuries, incorporating a comparison across age groups.

1.3.4 Chapter Five: Identifying Match Events and Calculating Their Propensity for Injury Within Schoolboy Rugby Union

Chapter five will describe the events occurring within youth rugby matches at different age groups, adding context to the epidemiological data collected in chapter four. When combined, it then describes and compares different contact events' propensity to cause injury.

1.3.5 Chapter Six: Characteristics of Schoolboy Rugby Union Tackles and Their Association With Head Contact

Chapter six describes the characteristics of both primary and adjust tackles occurring at different age groups. The association of these characteristics to head contact is then investigated for each age group, in the context of the ball carrier, primary tackler and adjust tackler.

1.3.6 Chapter Seven: General Discussion & Conclusions

Chapter seven synthesises the key findings from each chapter, summarising both the main findings and limitations of the thesis. These findings are then discussed, focusing on how they can be applied in the real world, before outlining the potential future research that could be conducted.

CHAPTER TWO

A REVIEW OF THE LITERATURE

2.1 Overview

This chapter investigates the literature surrounding youth rugby union, providing a contextual background for the subsequent work within this thesis. Specifically, this review of the literature will set the scene by introducing sports injury research, before addressing the current knowledge, and gaps within it, of injury epidemiology within rugby union. The use of match analysis to investigate match events and better understand injury is then discussed.

2.2 Sports Injury

2.2.1 The Benefits of Physical Activity

The benefits of a physically active lifestyle and participation in sport are well documented, with strong evidence suggesting that regular physical activity provides both physical and mental health benefits, regardless of age, sex or socioeconomic background (Panagodage Perera et al., 2021), contributes to the prevention of several chronic diseases and is associated with a reduced risk of premature death (Warburton, Nicol and Bredin, 2006).

One of the most extensively researched areas is the relationship between physical fitness and obesity. A study of 12-to-19-year-old males found that those who were unfit were 3.7 times more likely to have hypercholesterolemia and 1.3 times more likely to have low High Density Lipoprotein (HDL) cholesterol levels than those who were moderately or highly fit (Carnethon, Gulati and Greenland, 2005). For 9-to-11 year olds, research by Katzmarzyk et al. (2015) associated both obesity with sedentary behaviour and lower odds of obesity to moderate-to-vigorous activity. In the UK, it was found that vigorous activity was associated with a lower body mass index (BMI) and that 9-to-11-year-olds were more likely to reach physical activity guidelines if they had outdoor time after school, used active transport and took part in sport (Wilkie, Standage, Gillison, Cumming and Katzmarzyk, 2018). It has also been found that as little as ten minutes of moderate to high impact activities performed 2-to-3 days per week could have a positive effect on bone mineral density when combined with more general aerobic activities (Janssen and Leblanc, 2010), subsequently reducing the risk of osteoporosis and fractures (Chilibeck, Sale and Webber, 1995).

Whilst there are numerous physical benefits to physical activity and sport, participation has also been shown to improve self-efficacy (Wilkie et al., 2018) and develop social skills (Zekioglu, Tatar and Ozdemir, 2018), both of which have benefits outside of sport. A study of American college students found that those who met vigorous physical activity recommendations were less likely to report poor mental health and perceived stress (VanKim and Nelson, 2013). Several studies have investigated the effect of exercise on depression, all finding significant improvements in at least one depressive symptom when participants conducted 60-to-90 minutes of exercise per week over an 8-to-12-week period (Annesi, 2005; Norris, Carroll and Cochrane, 1992; Goldfield et al., 2007).

2.2.2 The Impact of Sports Injury

Youth athletes undergo intense periods of physiological, biomechanical and psychosocial growth (McKay, Cumming and Blake, 2019), so a balance must be found between the benefits of taking part in physical activity and sport and the risks associated with it. A review by Sabato, Walch and Caine (2016) highlighted that elite youth athletes, especially those who specialise early, are regularly exposed to psychological stress and are at greater risk of burnout, disordered eating and compromised mental well-being. Generally, evidence suggests that the more activity and higher the intensity, the greater the health benefit (Janssen and Leblanc, 2010), but there is also an increased risk of an individual sustaining a sports related injury (Nicholl, Coleman and Williams, 1995). More often than not, sports injuries are not severe and athletes will fully recover (Kujala, Orava, Parkkari, Kaprio and Sarna, 2003), but in some cases athletes will never return to sport. Sporting organisations may be losing a great deal of talent due to injury and, if society perceives that the risk of taking part outweighs the benefit, injuries could affect the popularity and participation levels of certain sports.

One of the most obvious impacts of injuries is player health. Whilst very rare, catastrophic injuries and those resulting in permanent disability do occur, primarily caused by direct forceful impact to the head or spine (Zemper, 2010). Much more commonly, head impacts result in concussion, 5% to 10% of which result in persistent symptoms (McCrory, Meeuwisse, Kutcher, Jordan and Gardner, 2013). A concussion is a "traumatically induced transient disturbance of brain function and involves a complex pathophysiological process" which can cause headaches, dizziness and reduced reaction times in the short-term (Harmon et al., 2013). A study by Harriss et al. (2020), which focused on adolescent sport-related concussions, identified additional symptoms such as trouble falling asleep, irritability, sadness, anxiousness, head pressure, sensitivity to noise and light and an overall feeling of "don't feel right". Hunzinger, Caccese, Costantini, Swanik and Buckley (2021) found that a younger exposure to collision sports and repetitive head impacts was not associated with worse patient-reported outcomes, but that a history of concussion was. There is concern that, if a player returns to play too quickly, this may increase the risk of a second concussion and that recurrent concussions could cause long-term neurological impairment. It has been suggested that following a career in contact sport there is a potential for long-term health issues, which could include the development of Alzheimer's dementia, mild cognitive impairment and depression (Prien, Grafe, Rossler, Junge and Verhagen, 2018). Although this has been suggested, causality has not been established (McCrory et al., 2013).

Another common concern regarding the participation of children in sport is that their tolerance may be exceeded by the mechanical stresses of the sport. During the pubescent growth spurt, bone mineralization may be slower than bone growth, rendering the bone more porous and prone to injury during this period (Caine, Maffulli and Caine, 2008). There is also evidence that rapid changes in size may make young athletes more susceptible to musculoskeletal injuries, especially when combined with the increasing demands of their sport (McKay et al., 2019). Most stress-related conditions do not result in growth complications, however there is evidence that stresses of sufficient duration and intensity may result in pathological changes of the growth plate, which would disturb growth (Maffulli, Longo, Gougoulias, Loppini and Denaro, 2010). A study by Whittaker et al. (2019) found that individuals who had experienced youth sport-related knee injury felt more total and intermittent pain, had a higher BMI and FMI (Fat Mass Index), weaker knee extensors and flexors and poorer balance than controls, three to ten years post-injury. This suggests that these injuries can have a significant impact in the short and medium-term, but also highlights the importance of physical activity in preventing obesity. Long-term, athlete populations have been found to have more degenerative changes in their joints and spine than non-athletes, with the development of premature osteoarthritis of lower limb joints being one of the most common adverse effects of vigorous physical activity (Kujala et al., 2003; Sabato et al., 2016). Due to the increased exposure to injury risk, former athletes may actually have more physical and psychological barriers to physical activity than the general population later in life (Russell, Tracey, Wiese-Bjornstal and Canzi, 2017).

Alongside the physical and psychological impact of youth sports injuries, there is also an economic impact (Davies et al., 2020). A study of admissions in two Oxfordshire hospitals found that under-19 year-olds account for almost half (47%) of all sports-injury-related emergency department visits (Kirkwood, Hughes and Pollock, 2019). Although, it is important to recognise that young people play sport more frequently than adults. For boys, the most common sports resulting in a hospital admission were football (1st), rugby union (2nd) and rugby league (3rd). As visits to the National Health Service (NHS) are not paid for by insurance companies, the true cost of sports injuries in the UK has not been determined, however, an American study found that youth sport injuries in Florida cost $24 million for inpatient care (average $6039 per visit) and $87 million for emergency department care (average $439 per visit) over a five-year period (Ryan, Pracht and Orban, 2019).

Alongside the cost to society, a study by Abernethy and MacAuley (2003) found that 59% of pupils missed time from school as a result of a sports injury, resulting in 32% of parents requiring time off of work. Whilst this study was limited to a single hospital, rugby was found to be responsible for the most injuries. It is possible that contact sport injuries more commonly require immediate treatment and ongoing rehabilitation than injuries sustained during non-contact sports, increasing players’ time away from education and the impact on their families. This is supported by the findings of Mitchell, Pecheva and Modi (2021), who collected sports injury data from a fracture clinic over the course of one year in a British hospital. Football was found to be responsible for the highest number of fractures (n=323, 47%), with rugby responsible for the second highest number (n=95, 14%). The proportion of rugby-related fractures requiring surgery (n=21, 22%) and physiotherapy (n=30, 32%) was significantly higher than the mean of all other sports injuries, thus incurring a greater financial cost.

2.2.3 Sports Injury Research

Sports injury research is underpinned by the principles of injury epidemiology, the study of the distribution and determinants of injuries and events in specified populations, as well as the application of the findings in order to prevent injuries and promote safety (Sadeghi-Bazargani, 2012). Arguably, the most well-known framework for sports injury research is the sequence of prevention, created by van Mechelen et al. (1992) (chapter one) (figure 1.1). Whilst it was acknowledged that this model has been a valuable tool in guiding injury research, Finch (2006) proposed a new model: Translating Research into Injury Prevention Practice (TRIPP) (figure 2.1). The TRIPP model extends the sequence of prevention by acknowledging and addressing the need for effective implementation. This is done by seeking to understand the context in which the preventative intervention will be implemented.

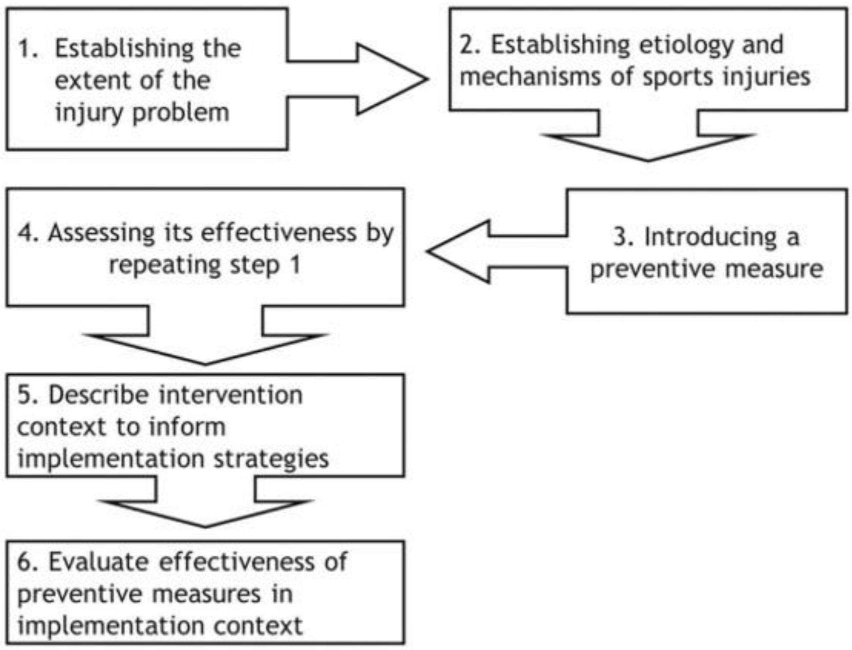

Figure 2.1: The "Translating Research into Injury Prevention Practice (TRIPP)" Model (Finch, 2006)

Regardless of which model is adopted, the first two stages remain the same, requiring an understanding of injury epidemiology within a given population or sport. This data is collected through injury surveillance, a standardised, routine and ongoing process of collecting data relating to injury occurrence and its causes (Finch, 1997), which drives the development of injury prevention strategies (Finch and Staines, 2018). England Rugby has numerous injury surveillance projects (England Rugby, 2021c), covering the professional, Championship, British Universities and Colleges Sports (BUCS) Super, community and youth games; with the latter informing chapters four and five of this thesis. Countries such as New Zealand also have substantial injury surveillance systems in place, which utilise the information provided by a personal injury insurance scheme, the Accident Compensation Corporation (ACC) (Quarrie, Gianotti and Murphy, 2020). Whilst this allows rugby-related injury records to be investigated for players of all ages, the majority of the world's surveillance systems are only in place at the elite level (Williams, Trewartha, Kemp and Stokes, 2013), despite the fact that the majority of the world's playing population are sub-elite (World Rugby, 2018). This, however, is likely because professional players fall under the duty-of-care of their employers, who implement these systems. Although there are some good examples of injury surveillance programmes, such as those mentioned above, they are lacking in most countries, especially within the youth and community settings (Freitag, Kirkwood and Pollock, 2015a).

Much of the epidemiological research into youth rugby injuries has shown large inconsistencies in data collection procedures (Freitag et al., 2015b), limiting the value of individual studies and the ability to compare them. One of the most important issues is the definition of injury, as this determines the threshold at which an injury is reported (Hammond, Lilley, Pope and Ribbans, 2011). Two of the most common definitions are time-loss injuries, requiring the player to have a minimum period (usually 24 hours or 7 days) unable to fully participate in training or matches, and medical attention injuries (Fuller et al., 2007b). This results in a wide range of injury rates (Bleakley et al., 2011). A similar issue can be found when calculating the incidence of injury. This is commonly calculated based on either time or athlete exposures (Knowles, Marshall and Guskiewicz, 2006). This can be problematic as each athlete exposure may not be equal in duration. In an attempt to improve the reliability and consistency of studies, consensus statements were created to guide studies of injury within both professional (Fuller et al., 2007b) and community rugby (Brown et al., 2019).

2.2.4 Summary

Whilst taking part in sport has numerous physical, mental health and social benefits for children, there is an inherent risk of injury. Most injuries are not serious, but those that are result in serious consequences, both short-term and long-term, and affect players, their families and society as a whole. For these reasons, injury prevention strategies must be created, but regardless of which model is used to develop them, injury must first be understood within the specific population they are being designed for. It is important that epidemiological research focusing on rugby adheres to the consensus statement on injury definitions and data collection procedures (Fuller et al., 2007b) to ensure that studies can be compared and research built upon.

2.3 Epidemiology of Injury in Rugby Union

2.3.1 Injury Within Youth Sport

At the professional level, the incidence of rugby union injuries may be considered high when compared to other team sports (Brooks, Fuller, Kemp and Reddin, 2005a; Brooks and Kemp, 2008; Williams et al., 2013), but it is comparable to other full contact collision sports, such as rugby league (Gissane, Jennings, Kerr and White, 2002; Hoskins, Pollard, Hough and Tully, 2006), ice hockey (Lorentzon, Werden, Pietel and Gustavsson, 1998; McKay, Tufts, Shaffer and Meeuwisse, 2014) and American football (Meyers and Barnhill, 2004). A review into youth sport injury rates by Caine et al. (2008) found that the highest rates of injury per 1000 hours of exposure (injuries / 1000h) were for ice hockey (5.0-34.4 injuries / 1000h) and rugby (3.4-13.3 injuries / 1000h). However, per 1000 athlete exposures, the greatest incidence was for cross country running (10.9-15.0 injuries / 1000 athlete exposures), American football (3.5-16.2 injuries / 1000 athlete exposures) and soccer (2.4-17.0 injuries / 1000 athlete exposures). It should be noted that no studies into rugby captured in this review reported injuries per 1000 athlete exposures, so it is not possible to tell where they would sit in comparison to these three sports. This review is now quite old and as several of the studies within this review combined both match and training data, investigated populations from different countries and age groups, had short data collection periods and wide variations in injury and incidence definitions, it can be challenging to make comparisons between sports.

Whilst multi-sport surveillance systems are in place in the United States, such as the National Collegiate Athletic Association's Injury Surveillance Programme (Kerr et al., 2014) and the High School Reporting Information Online System (Rechel, Yard and Comstock, 2008), they do not exist within England. However, hospital data can provide some insight across sports (section 2.2.2). One study which did seek to address this issue by comparing the rates of different youth sports was by Barden, Quarrie, McKay and Stokes (2021). This study found that rugby union had an injury incidence of 51 injuries / 1000h, which was found to be lower than that of American football (86 injuries / 1000h). The injury incidence within rugby league (24 injuries / 1000h) and basketball (43 injuries / 1000h) was also described, but soccer was found to have the lowest injury incidence (16 injuries / 1000h) of all male sports. As a consistent data collection methodology was employed, this allowed meaningful comparisons to be made across sports within an English setting. Whilst this is the case, limited data was collected (9-135 injuries per sport) and the teams captured represented the elite level of their sports and older players (>17 years) which, when combined with the fact that only match data was collected, may explain why the incidence rates are higher than those found by Caine et al. (2008). A study by Junge, Cheung, Edwards and Dvorak (2004) compared soccer and rugby union injuries in New Zealand. The players involved were of a similar age to those captured by Barden et al. (2021) and it was also found that rugby union (28.3 injuries / 1000h) injuries occurred more frequently than soccer (16.2 injuries / 1000h) injuries. Injuries not resulting in absence were also captured (soccer: 31.3 injuries / 1000h; rugby union: 101.5 injuries / 1000h), highlighting the issues around comparing studies with differing injury definitions.

Whilst the injury rates within individual sports have been investigated, research is limited, especially within England. Many of the studies are dated and it is difficult to compare the studies that there are. It appears that youth rugby follows a similar trend to the professional game as it has a higher injury incidence than other team sports, but is comparable to other contact sports.

2.3.2 Injury Within Rugby Union

2.3.2.1 Adult Rugby Union

To date, rugby injury epidemiological research has largely focused on male international and professional players, with less of a focus being placed on young players (Viviers et al., 2018; Williams et al., 2013). What is clear is that injuries recorded during training have a far lower injury incidence than those reported during matches, at all levels of the game (Williams et al., 2013; Palmer-Green et al., 2013; Palmer-Green et al., 2015; Viviers et al., 2018). A meta-analysis by Williams et al. (2013) found that professional rugby players had a mean match injury incidence of 81 injuries / 1000h and mean severity (time to return to full participation) of 20 days. The 2019/20 Professional Rugby Injury Surveillance Project (PRISP) report (England Rugby, 2020c) quoted a similar injury incidence for English professional players (88 injuries / 1000h), but a higher injury severity (38 days). Williams et al. (2013) also found that injury incidence was highest within an international setting (123 injuries / 1000h), however it was highlighted that the incidence for international matches was inflated by a study of the 2003 rugby world cup squad which reported an injury incidence of 218 injuries / 1000h (Brooks, Fuller, Kemp and Reddin, 2005b). When excluded from the analysis, the mean incidence for the international level and top level of professional clubs were similar, at 90 and 91 injuries / 1000h, respectively. No differences in the severity of injuries were found across levels, however time lost is likely affected by numerous factors, including both the resources available to players and the pressure to return to play (Creighton, Shrier, Shultz, Meeuwisse and Matheson, 2010).

One theme that runs throughout studies of injury within rugby is that a higher injury incidence is associated with a higher level of play (Williams et al., 2013; Palmer-Green et al., 2013; Leahy et al., 2019; Viviers et al., 2018). It has been suggested that this could be due to the increased size and strength of players, higher levels of competitiveness or more efficient reporting of injuries (Williams et al., 2013), although it is likely a combination of these. Yeomans et al. (2018) performed a meta-analysis of men's amateur rugby injuries and found an injury incidence of 47 injuries / 1000h, concluding that this was lower than at the professional level, but higher than that seen in a youth setting. A study by Roberts et al. (2013) was included within this review and found an injury incidence of 17 injuries / 1000h and a mean severity of 7.6 weeks in English men's community rugby. As injuries were only recorded if they resulted in eight or more days lost from sport, it is challenging to draw conclusions to other studies, which more commonly use medical attention and 24-hour time-loss definitions.

2.3.2.2 Youth Rugby Union

Studies into both sub-elite adult and youth rugby have a much greater variability in data collection procedures and study settings than elite levels of the sport (Freitag et al., 2015a), although much of this research was conducted before the introduction of the consensus statement (Fuller et al., 2007b). A review of adolescent rugby injuries by Bleakley et al. (2011) stated an overall match medical attention injury incidence of between 27.5 and 63 injuries / 1000h. For injuries resulting in a minimum of 24 hours' time lost, the incidence was found to be between 11.4 and 28.3 injuries / 1000h. A review of 35 studies by Freitag et al. (2015b) found a pooled injury incidence of 27 injuries / 1000h, regardless of injury definition or age. The majority of the studies included within this review reported injuries per 1000 player-hours, but others also reported injuries per 100 or 1000 player-games, 1000 match exposures, 1000 athletic exposures or 1000 player-seasons. Of the studies reporting injuries per 1000 hours, the incidence was found to be between 4 (under-10-to-under-13) and 130 (14-to-18 year-olds). For the younger group, a 7-day time-loss definition was used, whereas any physical complaint was registered as an injury for the older group, again highlighting the issues with varying definitions. Given the association between age and injury incidence, studies which pool data may be masking differences between age groups (Tucker, Raftery and Verhagen, 2016).

The schoolboy population has consistently been shown to have a lower injury incidence than that of academy players (Leahy et al., 2019; Palmer-Green et al., 2013), which is consistent with the evidence that injury incidence increases with playing level. Palmer-Green et al. (2013) found the 24-hour time-loss injury incidence for under-18 English schoolboy players to be 35 injuries / 1000h and academy players to be 47 injuries / 1000h, the same as the men's amateur incidence found by Yeomans et al. (2018). Whilst the incidence was higher for the academy players, there were no significant differences found in the severity of their injuries (schoolboy: 30 days; academy: 32 days). The injury incidence of schoolboy players was higher than reported in several other studies of youth rugby with the same injury definition (Archbold et al., 2017; Freitag et al., 2015b), but this is likely because they were under-18 players; another theme which runs through the literature is that injury incidence increases with age (Freitag et al., 2015b; Haseler et al., 2010; Viviers et al., 2018).

Haseler et al. (2010) investigated youth rugby injuries within an English community rugby club and quoted an injury incidence of 11.9 injuries / 1000h for under-9 to under-12 players and 32.3 injuries / 1000h for under-13 to under-17 players. However, these findings were only based on 39 injuries captured within a single season. Whilst the incidence of injury appears to increase with age in this study there was no direct comparison of age groups, however the under-10 and under-17 age groups' 95% Confidence Intervals did not overlap, suggesting that there is a significant difference between these groups. An unpublished study by Hislop (2017) investigated exposure and injuries within privately-funded English traditional rugby playing schools, finding injury incidence to be 23 injuries / 1000h for under-15, 24 injuries / 1000h for under-16 and 31 injuries / 1000h for under-18 year old players. One further study of English schoolboy rugby was conducted by Barden and Stokes (2018) over three seasons and used a 24-hour time-loss definition. As expected, the elite Achieving Academic and Sporting Excellence (AASE) players had a higher injury incidence (77 injuries / 1000h) than the sub-elite non-AASE players (34 injuries / 1000h). Whilst this provides a more recent insight into the injuries sustained at different levels, this study did focus on a single college and did not investigate differences between age groups, grouping 16-to-19-year-old players. Whilst there has been some research into the epidemiology of injuries within an English setting, it has generally not investigated age-related differences.

The injury incidence of youth rugby injuries has been investigated in other settings. In Northern Ireland, Archbold et al. (2017) found a similar rate of injury (incidence: 29.1 injuries / 1000h; mean age: 16.9 years) as the English studies. Within a South African tournament setting (2011 and 2012), the medical attention injury incidence for under-13 players was found to be 64.6 injuries / 1000h, compared with 54.5 injuries / 1000h at under-16 and 52.1 injuries / 1000h at under-18 (Brown et al., 2015b). A similar trend was seen in the same setting, but over a longer period (2011 to 2016), by Sewry et al. (2018), concluding that injury risk decreased with increasing age (under-13: 23.9 injuries / 1000h; under-16: 22.2 injuries / 1000h; under-18: 17.2 injuries / 1000h). This is unusual and may be due to the fact that a medical attention definition was used; it is possible that under-13 players are less robust and more likely to report minor injuries. It is also possible that the stated incidence rates are higher than would be seen during a normal season as, within a tournament, there is less time to recover between games and players may have become fatigued. This is evidenced by the fact that the rate of tackle-related injuries was higher in the final quarter of matches and, as fatigued players may be less able to tackle safely and efficiently (Davidow et al., 2020), this could have increased the rate of injury. A higher injury incidence later in the game is something that has been identified at all levels of the game (Archbold et al., 2017; Roberts et al., 2013; Williams et al., 2013).

In a study of insurance claims in New Zealand, it was found that the number of injury claims per 1000 players per year for males was higher at older age groups (5-6 years old:

10.8; 7-12 years old: 93; 13-17 years old: 448; 18-20 years old: 766; claims per 1000 players per year) (Quarrie et al., 2020). Whilst incidence was calculated, it was based on estimated exposure. A study of players in New Zealand which did capture exposure reported an injury incidence of 20.0 injuries / 1000h at under-13, 25.0 injuries / 1000h at under-15 and between 25.6 (fifth fifteen) and 65.8 injuries / 1000h at under-18 (first fifteen) (Durie and Munroe, 2000). On the surface, the under-13 and under-15 injury rates appear low given that injuries were recorded due to any physical complaint, however this is probably due to the fact that training injuries and exposure were also recorded within this data. Two Australian studies, which used a medical attention definition, reported an overall injury incidence of 23.7 injuries / 1000h (9-to-18-year-olds, tournament) (Leung et al., 2017a) and 31.8 injuries / 1000h (10-to-18-year-olds, season) (Leung, Franettovich Smith and Hides, 2017b). There were noticeable differences between the rates of the same age groups across the two studies (tournament vs season; under-13: 9.7 vs 22.7 injuries / 1000h; under-15: 35.9 vs 23.3 injuries / 1000h; under-18: 14.8 vs 56.2 injuries / 1000h), which may be due to the fact that one study investigated injuries within a tournament (n=332) and the other in a single school's season (n=80). In this instance the injury rates were generally lower in the tournament setting, highlighting the variation that can be found in different settings and the importance of investigating the specific population which you wish to create an injury prevention strategy for.

Less than half of the studies of injury within youth rugby report injury severity (Freitag et al., 2015b; Bleakley et al., 2011). One study which did was by Archbold et al. (2017) (mean age: 16.9 years), who found mean severity to be 23.8 days. Of the 426 injuries which were recorded, 10.1% were considered minor (<7 days), 40.8% considered moderate (7-28 days) and 49.1% considered severe (>28 days). This study found severe injuries to be the most common, which is unlike the findings of other studies at both the youth (Freitag et al., 2015b; Haseler et al., 2010) and professional (Williams et al., 2013) levels, where moderate injuries are most common. The mean severity was similar to that found in an English setting by both Barden and Stokes (2018) (AASE: 20 days; non-AASE: 19 days) and Palmer-Green et al. (2013) (academy: 33 days; schoolboy: 27 days); neither of which found significant differences between the level of play. As is the case for injury incidence, very few studies have investigated the differences in injury severity between age groups, however it does appear that injury severity is similar at all levels of the youth game.

At both the professional and community levels the lower limb has been shown to be the most common injury site (Williams et al., 2013; Roberts et al., 2013), however the findings of studies into youth rugby have been varied. Archbold et al. (2017) (6.9 injuries / 1000h) and Haseler et al. (2010) (6.1 injuries / 1000h) both found the head / face to be the most common site of injury, Palmer-Green et al. (2013) found the lower limb (schools: 16.6 injuries / 1000h) to be the most common and Barden and Stokes (2018) found the head / face to be highest for AASE schools (22 injuries / 1000h) and the shoulder to be the most common for non-AASE schools (5 injuries / 1000h). The type of injury which was found to be most common also varied, with Archbold et al. (2017) finding it to be sprains (9.1 injuries / 1000h), Palmer-Green et al. (2013) (schools: 14 injuries / 1000h) finding it to be ligament (non-bone) joint injuries and Barden and Stokes (2018) finding it to be both central / peripheral nervous system (AASE: 24 injuries / 1000h) and ligament (non-bone) joint (non-AASE: 11 injuries / 1000h) injuries.

Given the high incidence of head / face injuries and concerns around concussion in a youth setting, this diagnosis was highlighted in several studies, accounting for between 8% and 26% of all injuries (Archbold et al., 2018; Haseler et al., 2010; Barden and Stokes, 2018; Palmer-Green et al., 2013). For comparison, 16% of all community rugby injuries (England Rugby, 2020a) and 19.8% of all premiership rugby injuries (England Rugby, 2020c) were reported to be concussions in the 2019/20 season. A review of concussion within rugby union identified 10 studies reporting concussion within schoolboy rugby, stating a pooled match concussion incidence of 0.6 / 1000h (Gardner, Iverson, Williams, Baker and Stanwell, 2014). This figure is lower than that reported by Archbold et al. (2017) in Irish under-18 players (6 injuries / 1000h) and by Barden and Stokes (2018) in English sub-elite under-19 players (4 injuries / 1000h). This is likely because Gardner et al. (2014) also included data from younger players in their calculation and because concussion awareness and reporting has likely improved since, evidenced by the increase in both English professional and community rugby concussion incidence rates over the past ten years (England Rugby, 2020c; England Rugby, 2020a).

2.3.3 Risk Factors

As discussed, age (Freitag et al., 2015b; Haseler et al., 2010; Viviers et al., 2018), maturity (Caine et al., 2008; McKay et al., 2019; Maffulli et al., 2010), exposure type (Palmer-Green et al., 2013; Palmer-Green et al., 2015; Viviers et al., 2018), playing level (Palmer-

Green et al., 2013; Leahy et al., 2019; Viviers et al., 2018) and match period (Archbold et al., 2017) all have an effect on the risk of injury for young players. There are, however, numerous other risk factors, which can broadly be broken into two categories: intrinsic and extrinsic. Intrinsic risk factors are internal personal factors, which can further be divided into those which are modifiable and those which are non-modifiable, and help to identify a predisposed athlete. Extrinsic risk factors are external factors which athletes are exposed to during training and competition and are used to help identify a susceptible athlete (Meeuwisse, Tyreman, Hagel and Emery, 2007; Cameron, 2010; Saragiotto, Di Pierro and Lopes, 2014). It is important to acknowledge that injuries result from a complex interaction of multiple factors (Cameron, 2010) and that the risk to players is dynamic and can change frequently. Meeuwisse et al. (2007) proposed the dynamic, recursive model of etiology in sports injury (figure 2.2), which acknowledges that there are both intrinsic and extrinsic risk factors which can affect the risk of injury and that, post-recovery from injury, the previous injury may alter the risk of future injury.

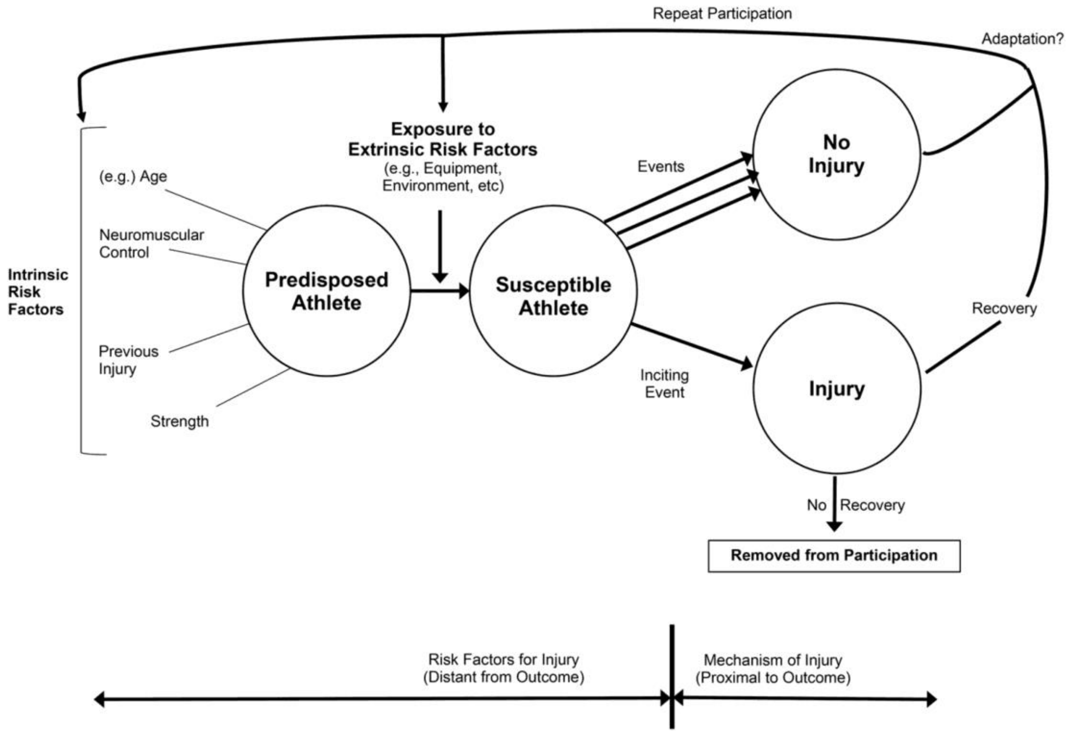

Figure 2.2: A Dynamic, Recursive Model of Etiology in sport injury (Meeuwisse et al., 2007).

2.3.3.1 Intrinsic Risk Factors

Possibly the most obvious intrinsic risk factor is the size of the competitor. Players often start playing rugby at a young age, where many individuals are relatively unskilled and there can be great variety in physical stature (Carter, 2015; Archbold et al., 2017). What is apparent is that player selection has tended to move towards larger players, with the average elite South African under-18 player's mass increasing by 5 kg and height by 1 cm from 2002 to 2012 (Durandt et al., 2009). In an investigation of English youth rugby players, it was found that academy players, who play to a higher standard than schoolboy players, were both taller and heavier (forwards: 7.5cm, 5.3kg; backs: 0.4cm, 6.1kg) (Read et al., 2018). Lee, Myers and Garraway (1997) found that injured sub-elite under-18 players had a greater BMI than non-injured players and, similarly, Archbold et al. (2017) found that players weighing more than 77 kg were at a greater risk of injury, however height was not found to be a factor. It is possible that larger players experience greater forces within contact events, subsequently increasing their risk of injury. As the anthropometric profiles of players within the same age group can vary greatly, the differences between players could also have an effect on the risk of injury (Nutton et al., 2012; Malina et al., 2019).

Risk relating to recurring (those of the same site and type) (Hamilton, 2011) and subsequent (different site or type) (Bleakley et al., 2011; Williams et al., 2013; Freitag et al., 2015b) injuries have not been extensively investigated within a youth setting, despite it being proposed that injury risk may alter following initial injury (Meeuwisse et al., 2007). Archbold et al. (2018) investigated recurrent injuries within an Irish schoolboy rugby population, finding that recurrent injuries only accounted for 5% of all injuries within a single season; lower than that of professional rugby (8-16%) (Williams et al., 2013). This was also lower than the proportion identified by Palmer-Green et al. (2013), who found that 11% of all injuries were recurrent in a schoolboy setting, however it was noted that this may be because Palmer-Green et al. (2013) recruited a higher level of rugby playing school. Most recurrent injuries (78%) in this setting occurred within two months of returning to play, which may be because schoolboy rugby players are less likely to consider their readiness to return than adult players (Hagglund, Walden and Ekstrand, 2006) and are more likely to engage in reckless behaviour (Archbold et al., 2018).

One of the major risk factors for sports injury is technique (Bahr and Holme, 2003). Several studies have described an association between proper technique and a reduced injury risk (Burger et al., 2016; Burger et al., 2017; Hendricks et al., 2016). Research has largely focused on the tackle as it has been shown to be both the most common event

(Roberts et al., 2015; Fuller et al., 2007a) and the one responsible for the most injuries (Burger et al., 2020). It has been found that players who see tackle training as important for preventing injuries generally reported safer behaviours during match play (Hendricks, Sarembock, Jones, Till and Lambert, 2017), although knowledge of safe and effective technique was not found to relate to technical proficiency within an academy setting (Den Hollander, Ponce, Lambert, Jones and Hendricks, 2021), highlighting the need for skills to be developed through coaching and training (Hendricks et al., 2018a). Alongside training to execute a range of technical skills (Hendricks, Lambert, Masimla and Durandt, 2015), it is also important that players have a high degree of physical fitness. It has been found that this can help players to resist technical fatigue for the duration of a match (Hendricks and Lambert, 2014; Tierney, Denvir, Farrell and Simms, 2018), which may reduce their risk of injury.

2.3.3.2 Extrinsic Risk Factors

The playing environment is a key extrinsic factor. Whilst pitch condition, pitch hardness and weather conditions have all been associated with an altered risk of injury in rugby union (Alsop, Morrison, Williams, Chalmers and Simpson, 2005; Nyagetuba, Saidi and Githaiga, 2015; Takemura, Schneiders, Bell and Milburn, 2007; Lee and Garraway, 2000), the use of artificial turf has become of increasing interest. To improve pitch availability and, subsequently, participation, many clubs and schools are now moving towards the use of artificial turf, however its effect on the risk of injury for schoolboy players is currently unknown. In elite rugby union, Williams, Trewartha, Kemp, Michell and Stokes (2016) found no significant differences between the incidence of injuries sustained on grass or artificial turf pitches, something which was also found within both male and female elite football (Ekstrand, Hagglund and Fuller, 2011). Whilst this is the case, Williams et al. (2016) did find that non-time-loss abrasion injuries were more common. Whilst the PRISP Report (England Rugby, 2020c) found the same injury incidence (84 injuries / 1000h) for matches on grass and artificial turf pitches, it did report that the severity (grass: 31 days; artificial turf: 38 days) and burden (days lost / 1000h) (grass: 2581 days / 1000h; artificial turf: 3196 days / 1000h) was higher for artificial pitches, although no explanation was offered as to the reason for this. In a community setting, the Community Rugby Injury Surveillance Project (CRISP) reported no differences in the incidence or severity of injuries on the two surfaces (England Rugby, 2020a). Fuller, Clarke and Molloy (2010) also investigated injuries on both surfaces within Hong King's Division 1. This study did identify that, although not found to be significant due to a very small sample size (n=5), anterior cruciate ligament (ACL) injuries were four times more common on artificial turf, something which might explain a higher severity and burden. Differences in the types of injury may also be the cause for this, as Ranson, George, Rafferty, Miles and Moore (2018) found that there was a higher rate of thigh haematoma and foot injuries on artificial turf; it was suggested that this may be due to footwear-to-surface interface factors.

Playing position has been investigated in numerous studies, but research within a youth rugby setting is limited. Regardless, the literature suggests that differences between forwards and backs are trivial at all levels of the game (Freitag et al., 2015b; Williams et al., 2013; Brooks and Kemp, 2011; Roberts et al., 2013). Brooks and Kemp (2011) investigated injuries across different playing positions. Whilst it was identified that there are differences in the injury profiles of different playing positions, there were no significant differences in absence due to injury. Previously, in a professional setting, the injury risk for forwards was found to be higher than that of backs (Bathgate, Best, Craig and Jamieson, 2002; Best, McIntosh and Savage, 2005; Targett, 1998), however an increased homogeneity in the involvements within contact events may have closed the gap between these two groups (Quarrie and Hopkins, 2007; Williams et al., 2013). Within a review of youth rugby injuries, Freitag et al. (2015b) identified seven studies which provided comparable data on rugby union, concluding that the proportion of injuries were similar for forwards (43.8-56.3%) and backs (43.6-56.3%). As the proportions stated for each playing position were wide-ranging and overlapped, this suggests that any differences between positions may be unclear due to small sample sizes. A more recent study by Barden and Stokes (2018) stated a sub-elite (non-AASE) injury incidence of 38 injuries / 1000h for forwards and 29 injuries / 1000h for backs. Elite (AASE) schoolboy forwards were found to have an injury incidence of 73 injuries / 1000h for forwards and 83 injuries / 1000h for backs. Whilst forwards and backs of the same playing level were not compared, the overlapping 95% Confidence Intervals suggest that there were no significant differences between groups. As youth players are more likely to play in different positions, although still within the forwards and backs groupings, than adult players, this makes understanding differences between playing positions challenging in this setting. This suggests that, within epidemiological studies investigating injury, grouping youth players into forwards and backs is sensible.

One risk factor which has been well researched is the event responsible for injury; this is also often referred to as the phase of play, inciting event or mechanism of injury. Whilst non-contact events, such as running and kicking, do occur frequently, contact events have been found to be responsible for around 88% of all injuries within sub-elite schoolboy rugby (Palmer-Green et al., 2013; Barden and Stokes, 2018). At all levels of the game, the tackle is responsible for the majority of injuries (Palmer-Green et al., 2013; Roberts et al., 2013; Williams et al., 2013), with a review by Bleakley et al. (2011) finding that 40% to 59% of all youth rugby injuries and 48% to 64.9% of concussions were sustained in the tackle. Barden and Stokes (2018) found that sub-elite 16-to-19 year-old schoolboy players sustained 19 tackle-related injuries / 1000h (55.9%) (tackling: 7 injuries / 1000h; tackled: 12 injuries / 1000h), similar to the schoolboy incidence of 18 injuries / 1000h found by Palmer-Green et al. (2013) (51.4%) (tackling: 8 injuries / 1000h; tackled: 10 injuries / 1000h). Unlike the findings of most studies, regardless of playing level, Archbold et al. (2017) found the incidence of being tackled (5.9 injuries / 1000h) to be slightly lower than that of tackling (8 injuries / 1000h). Generally, it is accepted that the tackle situation is responsible for the most injuries, but that the risk is greater to the ball carrier (tackled) than the tackler (tackling). Conversely, it is the tackler who is at a greater risk of concussion, with Cross et al. (2019) finding that they account for 70% of concussions in professional rugby. Regardless of playing level, the next most common injury-inciting events are similar, with the ruck / maul responsible for 8-32%, collision responsible for 6-9% and scrum responsible for 2-36% of all youth rugby injuries (Freitag et al., 2015b; Palmer-Green et al., 2013; Barden and Stokes, 2018; Williams et al., 2013).

2.3.4 Preventative Strategies

There have been numerous attempts to prevent injuries in rugby, generally focusing on primary prevention measures, which aim to prevent a first-time injury from occurring, as opposed to secondary measures, which seek to prevent recurrence (Piedade, Imhoff, Clatworthy , Cohen and Espregueira-Mendes, 2019). These strategies have included education, training and law changes.

In 2001, the New Zealand Rugby Union introduced a mandatory education programme, RugbySmart (RugbySmart, 2021), which aimed to educate coaches and referees about conditioning, safe technique and injury management. Something similar was introduced in both Australia, called Smart Rugby (Rugby AU, 2021), and South Africa, called BokSmart

(SA Rugby, 2021), based on the RugbySmart programme. An evaluation of RugbySmart's effectiveness (Gianotti, Quarrie and Hume, 2009) investigated both injury rates and injury prevention behaviours, finding that the rates of targeted injuries decreased from 2001 to 2005, whereas non-targeted injury rates did not. When 2005 behaviours were compared to 1996-98 behaviours, worthwhile effects were found for safe tackle, ruck and scrum technique and cool-downs. Crucially, this programme also resulted in a reduction of disabling spinal cord injuries arising from scrums (Quarrie, Gianotti, Hopkins and Hume, 2007). The BokSmart programme has also been evaluated (Brown, Gardner-Lubbe, Lambert, Van Mechelen and Verhagen, 2015a), finding that nine of eighteen behaviours improved from 2008 to 2012. These included catastrophic injury-preventing behaviours, post-injury compression, alcohol avoidance, mouthguard use and cooling down. In 2009, the "Are you ready to play rugby?" (now RugbyRight) programme was introduced in Scotland, which was tailored to specific age groups and focused on improving contact event technique, core stability, speed and agility (Scottish Rugby, 2021); the effectiveness of this intervention has not been evaluated. Another programme, a neuromuscular warm-up called Activate, was launched in England (Hislop et al., 2017). The programme was created for four age groups (under-15, under-16, under-18 and adults) and is broken down into four phases, which allows players to conduct progressively more challenging exercises throughout the season. An analysis of the age-grade programme found it to be effective for players who completed the warm-up at least three times per week, reducing match injuries by 72% and concussions by 59% (Hislop et al., 2017).

Whilst both education programmes and training have been shown to be effective, law changes may be the most effective way to reduce injury risk within sport, due to the mandatory nature of them. An investigation of 464 tackles resulting in the need for a Head Injury Assessment (HIA) in professional rugby (Tucker et al., 2017b) found that active shoulder tackles, front-on tackles, upright tackles and high speed or accelerating tacklers increased the likelihood of an HIA being required. Importantly, head contact between a tackler's head and the ball carrier's head or shoulder was significantly more likely to result in the need for an HIA than contact below the level of the shoulder. A more recent study by Cross et al. (2019) investigated the association between tackle characteristics and concussion. This study also found that an accelerating or high speed tackler was at a greater risk and that the risk of concussion was substantially higher when there was head-to-head contact. Another angle was taken by Tierney, Lawler, Denvir, McQuilkin and

Simms (2016), investigating direct head impacts in professional rugby. This study again highlighted that high speed tackles were an area of concern, but that tackler head placement, foot planting and the difference in ball carrier and tackler mass were also important factors. Tierney, Richter, Denvir and Simms (2018) also investigated head linear acceleration, angular acceleration and change in angular velocities in tackles of different heights. It was concluded that tackle height strongly affects the head kinematics of the ball carrier and that tackle height should be lowered to below the chest. Given the mounting evidence that a reduction in tackle height would be beneficial to player welfare, a reduction in tackle height was trialled in the English Championship (Stokes et al., 2021b). It was found that the intervention did alter the characteristics of the tackle, reducing the amount that tacklers made contact with the ball carrier's head and neck by 30%, but did also increase the rate of tackler concussion. However, it should be acknowledged that this was not significant and was due to a high number of concussions during one particular round of competition, rather than an increase in rates throughout the trial period. Whilst something similar is being trialled within English age-grade rugby (England Rugby, 2021a), law changes must be informed by data (Freitag et al., 2015a). It is particularly important that the characteristics of concern, such as tackle direction, speed and height, are investigated. As the reporting of concussions and filming of matches is limited within a youth setting, it may be challenging to link concussions to match footage. For these reasons, it may be more beneficial and realistic to relate characteristics of the tackle to head contact.

2.3.5 Summary

Whilst research has investigated schoolboy rugby injuries, wide variations in definitions and methodologies make drawing conclusions challenging. Much of the research in this area is dated and, despite the fact that the risk to players is complex and there is evidence suggesting that there are differences between age groups, studies continue to pool data due to small sample sizes. To date, there has been no investigation and comparison of the epidemiology of injuries at different age groups within an English schoolboy setting.

2.4 Match Analysis in Rugby Union

2.4.1 An Introduction to Match Analysis

Whilst the terms performance analysis and match analysis are often used interchangeably, match analysis is generally accepted as a part of performance analysis, focusing on team tactics, strategies, match performance and game events (Carling, Williams and Reilly, 2005). Performance analysis, a sub-discipline of sport science (Borms, 2009), is a much broader term, which also includes the evaluation of players and analysis of training. In recent years, numerous technologies have been utilised to measure individual or team performance; the most popular of these are Global Positioning Systems (GPS) and video analysis (Gomez-Ruano, Ibanez and Leicht, 2020). GPS is generally used for time-motion analysis, quantifying movement patterns in sporting situations by providing speeds, durations and distances of various locomotor patterns during the course of a game (Dobson and Keogh, 2007), whereas video analysis is primarily used for a notational analysis of matches. Notational analysis is defined as "an objective way of recording performance so that key elements of that performance can be quantified in a valid and consistent manner" (Hughes and Bartlett, 2002) and focuses on the recording and counting of match activities, rather than player movement patters (Quarrie, Hopkins, Anthony and Gill, 2013).

Franks and Miller (1986) investigated novice coaches' ability to accurately observe and recall the events occurring within football matches, finding that their mean recall was 42%. Further studies incorporated memory training, greater task specificity and greater domain experience, but coach recall remained at below 58% (Laird and Waters, 2017; Franks and Miller, 1991; Nicholls and Worsfold, 2016). What is clear is that a coach's view of the game may not always be correct or complete, so match analysis is often used to support coaching observations (Nicholls, James, Bryant and Wells, 2018). One of the first pieces of work in this area was conducted over a century ago by Evers and Fullerton (1910) but, following this, research was limited for decades. However, since the 1990's, match analysis has gained a prominent place in the literature (Sarmento et al., 2014), largely due to the advancement of technology (Colomer, Pyne, Mooney, McKune and Serpell, 2020), such as cameras, computers and software. The efficient and effective use of match analysis, which can be used to better interpret the complex nature of performance, can be used to provide comprehensive and objective feedback and is fundamental to learning and development (Butterworth, O'Donoghue and Cropley, 2017).

2.4.2 Understanding the Game

Historically, much of the match analysis research within rugby has had small sample sizes (Quarrie et al., 2013) and used a wide variation of definitions and methodologies, making it challenging to build on existing research and to make comparisons between different levels and populations. In recent years, sample sizes and the breadth of research has improved and, in an attempt to address issues with definitions and methodologies, a consensus statement on a video analysis framework of descriptors and definitions by the Rugby Union Video Analysis Consensus group (Hendricks et al., 2020) was created and is used to inform chapters five and six of this thesis.

Research in rugby has mainly been conducted on an elite population, generally focusing on performance indicators (Colomer et al., 2020), which relate to performance outcomes, such as possession and tackle success (Hughes and Bartlett, 2002), and physical demands, such as peak running intensities (Jones, James and Mellalieu, 2008). Importantly, much of the existing research is related to the demands of individual playing positions (James, Mellalieu and Jones, 2005; Roberts et al., 2008; Quarrie et al., 2013), rather than contact events. As the majority of injuries are caused by contact events (Hislop et al., 2017; Roberts et al., 2013; Williams et al., 2013), which a professional player may be exposed to over 11,000 times per season (Owens et al., 2021), it is important that they are understood, however there is very little information available about the frequency of them or the risk that a particular event will result in injury (propensity). A good example of the impact that this data can have can be found in football. Fuller, Smith, Junge and Dvorak (2004) analysed tackles from 123 matches across three FIFA (Fédération Internationale de Football Association) tournaments. Specific tackle actions which were associated with the requirement for medical attention were identified, resulting in the re-definition of foul play to reduce the risk of injury.

The quantity of events and their propensity to cause injury within adult rugby has been explored within two studies. The first focused on professional rugby during the 2003/04 and 2005/06 seasons (Fuller et al., 2007a), analysing 50 matches and identifying 22,842 contact events. This data was then combined with epidemiological data (760 24-hour time-loss injuries and 9,238 player-hours of exposure), which was taken from across two seasons, rather than just the matches which were analysed. It was found that the tackle (221 events / game) and ruck (143 events / game) were the most common events, but that collisions (10.5 injuries / 1000 events) had the highest propensity to cause injury. The days lost per 1000 events was also investigated and was highest for scrums (213 days / 1000 events) and collisions (200 days / 1000 events). It was concluded that tackles were responsible for the most injuries and time lost as they were the most common event, rather than because they were the most dangerous, meaning that efforts should be made to reduce the number of tackles. Collisions were 70% more likely to result in injury than tackles and, as they were rarely penalised, this required attention. However, a more recent (2013-15 seasons) study by Tucker et al. (2017a) found there to be an average of 158 tackles and 163 rucks per match, suggesting that the professional game may have changed since Fuller et al. (2007a) investigated match events. The second study calculating propensity was conducted in an English community setting (Roberts et al., 2015), utilising epidemiological data collected over three seasons (2009-12) and match analysis data from 30 matches. The methods were similar to those used by Fuller et al. (2007a), however a 7-day time-loss injury definition was chosen. The tackle (141 events / game) and ruck (115 events / game) were also found to be the most common event, with the illegal collision tackle having the highest propensity for injury (15 injuries / 1000 events) and being responsible for the most time lost per 1000 events (109 weeks / 1000 events).

It is likely that youth rugby games are not the same as senior rugby games (Read et al., 2016). In a comprehensive review of youth rugby match-play characteristics by Till et al. (2020) three English schoolboy rugby union studies were identified, but all of these focused on locomotor characteristics rather than contact events. It was concluded that match characteristics are likely to differ with age, but that no studies are currently available describing the technical and tactical elements of match play, which are commonly available for the adult game. A single study within under-18 academy rugby has investigated match events using accelerometers, Global Positioning Systems (GPS) and video analysis (Roe, Halkier, Beggs, Till and Jones, 2017). This study found that forwards were exposed to 26±9 contact events per game (9±5 tackles), compared to 14±6 for backs (6±3 tackles), but only a small number of matches were analysed (n=6). Whilst microtechnology can be used to count contact events, it is currently less accurate than video analysis for detecting collisions (Reardon, Tobin, Tierney and Delahunt, 2017) and does not distinguish between different types of contact events. Although coaches have been shown to value information provided by match analysis (Painczyk, Hendricks and

Kraak, 2018), little is understood regarding the match demands and events occurring within youth rugby (Waldron, Worsfold, Twist and Lamb, 2014b; Till et al., 2020) .

2.4.3 Understanding the Tackle

The tackle, defined as "any event where one or more tacklers attempt to stop or impede the ball carrier, whether or not the ball carrier was brought to the ground" (Hendricks et al., 2020b), is a highly technical and physical skill and an effective way of trying to regain possession of the ball and prevent the opposition from gaining territory (Burger et al., 2014; Fuller et al., 2007b). A review by Burger et al. (2020) identified 177 studies which were related to rugby union tackles, highlighting the amount of research in this area. It is likely that the tackle is so well researched, as discussed, as it has been found to be associated with team success (Hughes and Bartlett, 2002), is the most common match event (Roberts et al., 2015; Fuller et al., 2007a) and the one responsible for both the most injuries and concussions (Burger et al., 2020; Williams et al., 2013; Bleakley et al., 2011; Cross, Kemp, Smith, Trewartha and Stokes, 2016). These studies have been carried out in many different countries, across different playing levels and both in and out of laboratories. They have also covered a wide variety of topics, for both males and females, including injury rates, concussion and head contact, technique and player and coach attitudes (Burger et al., 2020). Whilst it is important that the specific population you are trying to understand is investigated, this broad range of research helps us to identify key themes across various populations and areas of interest for future research within the population we are interested in.

As has been highlighted, proper technique, for both the tackler and ball carrier, has been identified as a risk factor for injury (Burger et al., 2016; Burger et al., 2017; Hendricks et al., 2016). A study by Quarrie and Hopkins (2008) found that ball carriers were at the highest risk from tackles to the head / neck region, whereas tacklers were at higher risk when making low tackles. A more recent study by Suzuki et al. (2020) investigated factors related to the occurrence of concussion. It was found that the tackler was at higher risk if they contacted the ball carrier with their head / neck and that their head positioning and the direction of the tackle also had an effect on their risk. Fortunately, it does not appear that there is a trade-off between injury prevention and performance, with a review of rugby union tackles Den Hollander et al. (2021) concluding that "safe technique is effective technique". Of course, injury prevention and performance are not mutually exclusive, as if players are unable to play due to injury, they are unable to perform. The literature suggests that tacklers should drive with their legs, place their head to the side of and wrap their arms around the ball carrier, making contact with their dominant shoulder, as this results in improved control of the head. Ball carriers should avoid going into contact with their head down and should fend the tackler where possible, as this increases their likelihood of either offloading the ball or breaking the tackle (Tierney et al., 2018b; Hendricks, Matthews, Roode and Lambert, 2014; Hendricks et al., 2015b; Hendricks et al., 2020a; Burger et al., 2016; Burger et al., 2017; Sobue et al., 2018).

Most of the research in this area has focused on the elite game, with very little investigating tackles within a youth setting, despite the concerns around the tackle for younger players (Carter, 2015). In a study of 6618 tackle events by McIntosh, Savage, McCrory, Frechede and Wolfe (2010), it was found that players were more likely to conduct active shoulder tackles as they got older and that younger players were at a lower risk of tackle-related injury. Whilst no specific tackle characteristic was found to be associated with an increased risk of injury, there was a greater risk of injury when there were two or more tacklers. Burger et al. (2016) investigated under-18 tackle technique during the South African Craven Week tournaments (2011-13). In total 49 tackle-related injury events and 248 non-injury events were investigated and scored, based on technical criteria, and it was found that tackles with higher technique scores were associated with non-injury outcomes. Further analysis of these tackles highlighted that they were more likely to result in injury towards the end of a match (Burger et al., 2017). For ball carriers it was found that they were at greater risk when they were not aware of the impending contact and did not fend the tackler. For both ball carriers and tacklers, they were at greatest risk when the tackler made contact with their head / neck, rather than their shoulder / arm. It was concluded that there are numerous aspects of technique which affect the risk of injury.

From the same tournament (2011-2015), Brown et al. (2018) analysed 12,216 tackles from 99 matches, finding that 59% of illegal tackles, which were most commonly front-on, high tackles, were not sanctioned by the referee. Whilst this is better than at the professional level, where 94% of illegal tackles are not penalised (Fuller et al., 2010a), this is still concerning, especially as front-on tackles, head-to-head contact and head-to-shoulder contact have been found to increase the risk of a player requiring an HIA in professional rugby (Tucker et al., 2017b).

As the majority of head injuries in rugby occur when the head is impacted during a tackle (Roberts, Trewartha, England, Goodison and Stokes, 2017; Cross et al., 2019), Davidow et al. (2020) investigated the technique of tackles which resulted in head contact, compared to those which did not, in an adult professional and semi-professional setting. It was suggested that tackles resulting in head contact were technically deficient and that both the ball carrier and tackler are responsible for each other's safety. Davidow et al. (2020) concluded that coaches had a key role to play in educating players on this. Given that youth players generally see performance as more important than injury prevention (Hendricks, Jordaan and Lambert, 2012), coaches should take time to explain why injury prevention is important, as verbal explanations have been found to improve how important players view this subject to be (Hendricks, den Hollander and Lambert, 2019). To achieve this coaches themselves must be educated on the risks associated with the tackle and the value of teaching proper technique (Hendricks and Lambert, 2010). Whilst this is the case, even when coaches are aware it does not guarantee that this will relate to their training if they do not feel competent at teaching tackle technique, so it is important that coaches are educated on both theory and practical application (Hendricks et al., 2017). It has also been suggested that the risk of concussion could be reduced through training interventions. Specifically, those which improve peripheral vision, strengthen cervical muscles and reduce fatigue through conditioning programmes (Hendricks et al., 2016).

It has been highlighted that the tackle should be the focus of future interventions (Tucker et al., 2017a), but the characteristics of English schoolboy tackles are currently not understood. Given that the incidence of injury is thought to increase with age (Freitag et al., 2015b; Haseler et al., 2010; Viviers et al., 2018) and that tackles are responsible for the majority of injuries (Burger et al., 2020; Williams et al., 2013; Bleakley et al., 2011), it is reasonable to question whether the characteristics of tackles differ with age. As concussion is an area of concern in youth rugby, is primarily caused by the tackle and is linked to head contact (Tucker et al., 2017b; Cross et al., 2016), it is also important to understand the relationship between specific characteristics of the tackle and head contact. Throughout this thesis, head contact will be defined as "any clear head contact occurring in the tackle to either the carrier or tacklers" (England Rugby, 2018a). Currently, very few studies have accounted for multiple contextual variables, such as field location and the number of players involved in the tackle, limiting insights into player-opponent interaction and the effect of multiple factors (Colomer et al., 2020). The evidence suggests that player and coach education, tackle technique training and law change may help to reduce injuries, however this must be informed by data relevant to the population in which the intervention is being designed for (Tucker et al., 2017a).

2.4.4 Summary

Match analysis is a useful tool which provides coaches and researchers with quantifiable data that can be used to inform decisions. As differences in definitions and data collection procedures limit the ability to compare studies and build on existing research, future studies in this area should adhere to the consensus on a video analysis framework of descriptors and definitions by the Rugby Union Video Analysis Consensus group (Hendricks et al., 2020). Whilst there is a good understanding of player demands at the elite level, most studies do not focus on the events which cause injury and there is currently no data available on the events occurring within the youth game or their propensity to cause injury. It is also currently unknown what the characteristics of tackles within this setting are or which of these have the greatest association with head contact, despite concerns about concussion.

2.5 Rationale

This review of the literature has described the physical, mental and economic burden of injuries sustained within youth sport, highlighting the need for an improved understanding of them and the events by which they are caused. Currently, much of the research within rugby union has focused on the professional game and cannot be applied within a youth setting, due to differences in both the players and the game itself. Similarly, the evidence suggests that there are also differences between age groups and that the risk to specific populations is affected by a complex interaction of various risk factors, so “youth” should not be treated as a single population. Given that the laws of the game differ for each age group and that injuries are largely caused by contact events, context should be added to injury epidemiological data through the use of match analysis, helping to develop the understanding of the game, the number and type of events which are occurring and the risk posed by them. Investigating both injuries and match events, with a focus on the tackle, will provide a reference for coaches, enabling them to understand how the game differs at different age groups, and will lay the foundation for population-specific injury prevention strategies.

CHAPTER THREE

GENERAL METHODOLOGIES

The three studies described in this thesis investigate the nature of injury across various age groups within youth rugby. The first of these studies, chapter four, focuses on injury epidemiology, which required the collection of both injury and match data. This data was also utilised within chapter five but, alongside chapter six, focused on the analysis of matches and the events within them, requiring the collection and analysis of match footage.

3.1 Study Design & Setting

This thesis investigates rugby related injuries (chapter four and five) and the events associated with them (chapters five and six) in an English secondary school setting. The schools involved represent both privately funded independent schools and state funded schools, who were recruited as part of England Rugby's Youth Rugby Injury Surveillance Project. Epidemiological data was collected over the course of three seasons, spanning September 2017 to April 2020, with match footage also being collected during the first two seasons (September 2017 to April 2019).

3.2 Participants

Previous versions of the Youth Rugby Injury Surveillance Project ran from 2006-2008 and from 2013-2016. An existing database of school contact details (n=85) from the 2013-16 period was used for the first season's recruitment (table 3.1). This database was then built upon throughout the three seasons (season two: n=164; season three: n=278) with schools who enquired about the research project or who were recruited at England Rugby's "coach training days".

Schools were able to enrol multiple teams in the project, but they had to be boys' teams in the under-13 (U13), under-15 (U15) or under-18 (U18) age groups. At the start of each season, a "project coordinator" was nominated, who was the main point of contact for each team. They were generally a coach or physiotherapist.

During the first season, where U13 match footage was collected, any team which signed up to the project was able to request the filming of their matches. At the conclusion of the first season, the six teams who had provided the best quality U15 and U18 data, determined by the proportion of the season that had been captured and the quantity of missing data, were invited to take part in filming the following season. This was done to ensure that only the most reliable schools were involved, due to the cost of filming.

3.3 Sample Size & Recruitment

Recruitment for the collection of epidemiological data (chapters four and five) and match footage (chapters five and six) ran side by side, taking place in September and October 2017 for the first season. Recruitment then took place in May 2018 (epidemiological data and match footage) and May 2019 (epidemiological data) for seasons two and three, respectively. The data collection ran from September to April for each of the three seasons.

To aid with recruitment, the project had a web page with a way for schools to contact the research team (University of Bath, 2021). England Rugby also supported the Youth Rugby Injury Surveillance Project with the creation of a promotional video (England Rugby, 2018b), which was launched on their social media. Over the course of the three seasons, 35 different schools provided epidemiological data (table 3.1).

Table 3.1: Schools involved in the Youth Rugby Injury Surveillance Project.

	Asked To Take Part	**Agreed To Take Part**	**Provided Data**
Season	**Schools, n**	**Schools, n (% of Asked)**	**Schools, n (% of Asked)**
2017/18	85	41 (48)	19 (22)
2018/19	164	61 (37)	16 (10)
2019/20	278	57 (21)	21 (8)
Overall	284	111 (39)	35 (12)

During the recruiting period, each school within the database was sent an email outlining the purpose of the project and inviting them to take part. For schools who replied wanting to be enrolled in the project, a second email was sent explaining exactly what would be required and how the data would be used. The email also requested that the school decide which teams would be enrolled and who the project coordinator would be for each one.

One month before the start of the season, project coordinators were sent a team spreadsheet to collect data and a link to securely upload it. They were also provided with links to coach (APPENDIX J) and parent (APPENDIX I) consent and player assent (APPENDIX H) forms, which included information sheets (APPENDICES E, F & G). These were sent to the relevant individuals and completed using Online Surveys (previously Bristol Online Surveys) (Online Surveys, 2021). Schools who were not having their matches filmed had the relevant sections of the information sheets removed. Where filming was being conducted, consent for match officials (APPENDIX L) and opposition team coaches, who gave permission for their team to be filmed, (APPENDIX K) was obtained by the company filming the matches and sent back to the research team via email.

Ethical approval for the project was obtained from the University of Bath's Research Ethics Approval Committee for Health (REACH), under the code EP-17/18-167. Amendments were submitted and approved for both the 2018/19 and 2019/20 seasons.

3.4 Injury Epidemiology

This section describes the collection of epidemiological data and the variables associated with it, setting the scene for chapters four and five.

3.4.1 Data Collection

Each team was provided with a team spreadsheet (APPENDIX B), which was created using Microsoft Excel. If requested, paper alternatives were provided; one for recording match exposure (APPENDIX C) and one for recording injuries (APPENDIX D), with return envelopes. The project coordinator was responsible for filling in the data, which is used within chapters four and five, and was able to contact the research team throughout the season with questions. The team spreadsheet was comprised of several parts:

(1) Guide: This section introduced the project and the workbook and provided information on the benefits of taking part and how to input the data.

(2) Information: In this section the project coordinator could input general information on the team, such as school name, age group and season dates, which would automatically populate the rest of the spreadsheet.

(3) Squad List: A list of all players and staff members and their date of birth could be captured here.

(4) Exposure: Match data, including length of game, outcome, score, opponent and playing surface was input within this section.

(5) Injuries: Injury data was collected in this section and included the date of injury, return to play date, quarter, outcome, playing position and injury event, site and type. Each detail had a drop-down list to ensure uniformity across teams. There was also a notes section where free text could be added.

(6) Statistics: As data was added to the rest of the spreadsheet, this section would automatically update, providing instant feedback to them team. This section fed back on both performance and injury, with statistics such as wins and losses, points difference, season exposure, injury incidence and severity, injuries / game, games / injury and injury events, sites and types.

Before data was collected, a data management plan (APPENDIX A) was created and used to support the ethical approval application. Each team was given a "Files.Bath" link, so that they could upload the spreadsheet onto a secure University server. This data could only be accessed by the research team.

The project coordinator was asked to fill in the details and upload the spreadsheet before the start of the season, so that the research team could record the details captured in the information and squad list sections and check that the project coordinator understood the process. They were then asked to upload the spreadsheet every six weeks, so that the research team could identify and clarify any issues with the data. Finally, teams were asked to upload their spreadsheets at the end of the season.

As the coach and parental consent and player assent forms were returned, the research team monitored the replies against the names and dates of birth on the squad list. Once every individual had consented, the squad list tab was deleted for the purposes of data protection and anonymity. Once coach consent had been returned, the team's match exposure data could be used. If not all members of the team had completed the form when injury data was returned, the coach was sent a list of those who had and had not consented.

As the injury data was anonymous, the coach was asked to either confirm that the individual had consented or to ensure that they asked the player to complete the required form. If this had not have been achieved, the team would have been removed from the study. Similarly, the team would have been removed from the study if a member of the team had not given their consent. There were no instances where a team had to be removed due to issues with consent.

Both injuries and matches were tracked on a master spreadsheet, with injuries being checked to ensure that they fell within the period of match data provided by the team. If they did not, the additional exposure was requested, given that this would have highlighted that additional matches were being played. If this was not provided, the injury was removed. If data was missing, this was requested from the school. If the school was unsure of the answer or did not respond following a second attempt to follow up, this data was marked as “unknown”. If no (or estimated) time-loss was provided, these injuries were used within the incidence calculations, providing the research team was sure that these were 24 hour time-loss injuries, but not within the severity or burden calculations.

3.4.2 Variables

Throughout this thesis, the definitions and data collection procedures were based on the guidelines set out within the Consensus Statement on injury definitions and data collection procedures for studies of injury in rugby union by Fuller et al. (2007b).

An injury is classified as “any physical complaint, which was caused by a transfer of energy that exceeded the body’s ability to maintain its structural and / or functional integrity, that was sustained by a player during a rugby match or rugby training, irrespective of the need for medical attention or time-loss from rugby activities. An injury that results in a player being unable to take a full part in rugby training or match play should be referred to as a ‘time-loss’ injury” (Fuller et al., 2007b). For this thesis a 24-hour time-loss definition was used, where injuries were only recorded if a player was unable to take a full part in training or match play for more than 24 hours from midnight at the end of the day that the injury was sustained. Match exposure was classified as play between teams from different schools.

Injury regions, sites and types were kept the same as those used in previous iterations of the project. This was decided upon to ensure that there was uniformity with previous seasons of Youth Rugby Injury Surveillance Project and to allow for comparisons to be made with historical data. The regions, sites and types were based on those within the consensus but simplified and modified, as not all project co-ordinators were health care professionals. An unknown category was added and for injury types and it was decided that concussion would be considered a nerve injury. A comparison of thesis and consensus categories can be seen in tables 3.2 (injury region and site) and 3.3 (injury type).

Table 3.2: Comparison of thesis and consensus injury regions and sites.

Thesis		**Consensus**	
Injury Region	**Injury Site**	**Injury Grouping**	**Injury Location**
Head & Neck	Head	Head & Neck	Head / Face
	Neck		Neck / Cervical Spine
Upper Limb	Shoulder	Upper Limb	Shoulder / Clavicula
	Upper Arm		Upper Arm
	Elbow		Elbow
	Forearm		Forearm
	Wrist & Hand		Wrist
Trunk	Chest		Hand / Finger / Thumb
	Trunk & Abdomen	Trunk	Sternum / Ribs / Upper Back
	Thoracic Spine		Abdomen
	Lumbar Spine		Lower Back / Pelvis / Sacrum
Lower Limb	Hip & Groin	Lower Limb	Hip / Groin
	Pelvis & Buttock		Anterior Thigh
	Thigh		Posterior Thigh
	Knee		Knee
	Lower Leg		Lower Leg / Achilles Tendon
	Ankle		Ankle
	Foot		Foot / Toe
Unknown	Unknown		

Table 3.3: Comparison of thesis and consensus injury types.

Thesis	**Consensus**
Injury Type	**Injury Type**
Fracture	Fracture
Stress Fracture	Other Bone Injuries
Other Stress / Overuse Injury	Dislocation / Subluxation
Joint Dislocation	Sprain / Ligament Injury
Joint (Non-Ligament) Injury	Lesion of Meniscus, Cartilage or Disc
Ligament Injury	Muscle Rupture / Tear / Strain / Cramps
Cartilage Injury	Tendon Injury / Rupture / Tendinopathy / Bursitis
Muscle Injury	Haematoma / Contusion / Bruise
Tendon Injury	Abrasion
Bruising / Haematoma	Laceration
Cut / Abrasion	Concussion
Nerve Injury	Structural Brain injury
- Concussion	Spinal Cord Compression / Transection
Abdominal / Organ Injury	Nerve Injury
Vascular Injury	Dental Injuries
Non-Specific Injury	Visceral Injuries
Other	Other Injuries
Unknown	

In line with the consensus, injury events were classified as tackling, tackled, maul, ruck, lineout, scrum and other. Collision was altered to accidental collision to highlight that it was not a collision tackle and that the contact was not intended. Running and unknown events were also added. Playing positions were classified as forwards, backs or unknown. For U13, forwards were players 1 to 6 and backs were players 7 to 13. For U15 and U18, forwards were players 1 to 8 and backs were players 9 to 15. Match timing was also recorded for each injury and classified as: quarter 1, quarter 2, quarter 3, quarter 4 or unknown. The quarters last (minutes: seconds) 12:30, 15:00 and 17:30 for U13, U15 and U18 matches, respectively.

3.5 Match Analysis

Initially, this section describes how match footage was collected for use within chapters five and six. The remainder of this section focuses on how this footage was analysed and validated for use within chapter five.

3.5.1 Match Footage Collection

To obtain U13 footage (n=49) from participating schools during the first season, for use within chapters five and six, an external company specialising in filming sports matches (Cheers Mate) was employed. This company was given the contact details, with the permission of the school, of schools who had consented to having their matches filmed. These schools ensured that all of their players had consented to providing injury data for the epidemiological study. The company liaised directly with these schools, the opposition teams and the match officials before attending, gaining consent from the match officials and the opposition coach. The opposition coach was able to give permission for their team to be filmed, as they were not providing injury data. Had they not given their permission the match would not have been filmed, however this did not occur. The camera operators were given the following instructions:

(1) To ensure that the full match is filmed, from kick-off to when the end of the match is signalled by the referee.

(2) To keep the camera running throughout, even at half-time, to enable a single file to be loaded on the analysis software.

(3) To follow the ball but to zoom in to contact events, where possible.

(4) To film from the side of the pitch and from as high as possible.

Once filming was complete, a link was sent to the research team so that they could download the footage securely. Both the school involved in the project and the opposition team were also given access to this footage.

For the second season, a different filming company (Film My Match) and approach was taken to the filming of U15 (n=31) and U18 (n=58) matches. The six teams who had provided the best quality data the previous season were offered filming. Limited schools were selected to minimise logistical issues around organising the filming of matches and gaining consent. Teams were chosen in this manner as they were deemed more likely to continue with the project, enabling the collection of match footage for the entire season. Whilst there was sufficient high quality footage to enable the analysis of U13 games, the new company was chosen to ensure that the footage was as clear as possible. Their camera operators had more experience of filming rugby, had better quality cameras and, in many cases, were able to use a “HI-POD”. This is an extendable mast system that allowed for the filming of matches from a height of up to 31 feet (9.5 metres), resulting in a better view of the game. For gaining consent and receiving footage, exactly the same approach as the first season was used.

3.5.2 Match Coding Window

Match analysis is used to quantify game events and requires specialist software. Several options were considered, but Nacsport Pro Plus (Nacsport, 2021) was chosen, as it had all of the tools which were required for the analysis of both matches and tackles, for the best price. This software allows users to create their own coding windows, which are specific to the sport or event that they are analysing. In order to analyse the matches which had been recorded, a match event window (figure 3.1) was created. Each key event within the game was inserted as a "category", with further detail added in the form of "descriptors" (table 3.4).

An injury category was included to identify suspected injuries or those requiring medical attention. This allowed researchers to follow up with schools if potential injuries were identified within matches, but were not recorded as part of the injury surveillance. It also meant that these injuries could easily be identified, should this be required for future research.

Figure 3.1: Nacsport match event coding window.

The footage was checked to ensure that all of the matches were complete; any incomplete matches were excluded. Matches were incomplete for a variety of reasons, such as the camera operator missing the start of the match, issues with the camera during the game or the game being called off. From the remaining footage, twenty games were selected at random for each age group. These games were then analysed by a single coder, exported as an Excel file and cleaned. This included checking that the descriptors matched the correct categories and that the quarters started and stopped at the correct times. This data was then input into a master spreadsheet for analysis.

3.5.3 Variables

For chapters five and six, the definitions and data collection procedures were based on the guidelines set out within the consensus on a video analysis framework of descriptors and definitions by the rugby union video analysis consensus group (Hendricks et al., 2020). Alongside the video analysis consensus, England Rugby's Operational Definitions Manual (England Rugby, 2020b) was used to define events and characteristics. When both references had differing definitions, a decision on which to use was based on which best suited English schoolboy rugby match play and the quality of footage which was available. In some cases, the options for specific characteristics available within the consensus and operational definitions manual were "merged" to improve reliability and repeatability. Where a definition needed to be altered to suit the specific population, the definition was "modified". Where a suitable definition could not be found, an "original" definition was created. Table 3.4 sets out the definitions which were used for match analysis and their origin.

Table 3.4: Match event definitions and their origin.

Event	Origin	Definition
Match Descriptors		
Total Match Time	Original	The sum of the time played in the first and second halves; from kick-off until the referee signals the end of the half. For youth games the time should not be stopped.
Ball In Play Time	Consensus	The amount of time the ball is in the possession of any of the players or is in a position where either team can contest the ball. Time when play has been stopped by the referee is considered out of play and does not contribute to ball in play time.
Quarter	England Rugby (Modified)	Additional label to be added to ALL labels in the respective quarters of the game. For youth games, Quarter 2 and Quarter 4 would start exactly 1/4 of the match time after kick-off.
Contact Events		
Accidental Collision	Original	Where contact is made unintentionally; normally where one or more players are not aware of the situation.
Lineout	Consensus	A lineout is formed on the mark of touch. Each team forms a single line parallel to and half a metre from the mark of touch on their side of the lineout between the 5 m and 15 m lines. A minimum of two players from each team are required to form a lineout.
- Won	Consensus	Attacking team maintains possession of the ball after the line-out contest.
- Lost	Consensus	Attacking team fails to maintain possession of the ball after the line-out contest.
- Quick	Consensus	A quick line-out (quick throw) can take place before a line-out is formed and is observed when a player whose feet are both outside the field of play throws the ball parallel to or towards the thrower’s own goal line, between the mark of touch and the thrower’s own goal line, so that it reaches the 5 m line before it touches the ground or makes contact with a player.
Maul	Consensus	A maul begins when a player carrying the ball is held by one or more opponents, and one or more of the ball carrier's teammates bind on the ball carrier. A maul therefore consists, when it begins, of at least three players, all on their feet; the ball carrier and one player from each team.
Ruck	Consensus	A ruck is formed when at least one player from each team is in contact, on their feet and over the ball, which is on the ground. Once a ruck is formed, additional players joining the ruck to compete for the ball, without being guilty of foul play, are considered rucking.
Scrum	Consensus	A scrum is formed in the field of play when eight players from each team, bound together in three rows for each team, engage with their opponents so that the heads of the front rows are interlocked. Scrum engagement occurs when the front-row of each team make contact with each other.
- Won	England Rugby	The team putting the ball into the scrum secures possession and play continues.
- Lost	England Rugby	The team putting the ball into the scrum loses possession and play continues.
- Reset	England Rugby	The scrum process is re-started.
- Collapsed	Original	The scrum collapses.
Scrum Time	Consensus (Merged)	The time (in minutes: seconds) from the engagement to when the ball is played or the whistle is blown to reset the scrum.
Tackle	Consensus	A tackle is any event where 1 or more tacklers (player or players making the tackle) attempted to stop or impede the ball carrier (player carrying the ball) whether or not the ball carrier was brought to ground.
- Successful	Consensus (Modified)	When a tackle break does not occur, and either player goes to ground or the ball carrier is held up and cannot progress further, whether they offload the ball or not.
- Break	Consensus	The ball carrier successfully penetrates the attempted tackle and continues to advance.
- Incomplete	Original	The tackler makes contact, but actively decides not to complete the tackle. This is common after the ball is offloaded.
- Unsuccessful (Missed)	Original	There is no meaningful contact and the tackler fails to tackle the ball carrier, thus allowing the ball carrier to advance during open play.

Table 3.4 (Cont'd): Match event definitions and their origin.

Event	Origin	Definition
Match Events		
Clean Break	Consensus	The number of times a ball carrier moved through a straight line between two defenders, or a defender and the touch line, without being physically contacted by the defender.
Kick	England Rugby	Any kick that is executed within open play.
- Tap & Go	England Rugby	The ball is tapped from a free kick or penalty, also to be used for tap kicks that are kicked long, also kicks after a player has taken the mark in their own 22m.
- To Touch	Original	A kick that goes directly into touch.
- To Hand	Original	A kick that is caught by any player. It must be caught without bouncing or being dropped.
- To Field	Original	A kick that lands on the pitch.
- At Goal	England Rugby	An attempt to kick for goal in play whilst dropping and kicking the ball simultaneously.
- Penalty	England Rugby	A kick at goal after a penalty has been awarded.
- Conversion	England Rugby	A kick at goal after a try has been scored.
Pass	England Rugby	The ball is received from a teammate's pass / offload or intercepted from the opposition's pass.
- Offload	England Rugby	A player has taken the ball into contact and is able to move the ball to a teammate before hitting the ground.
Try	England Rugby	A player successfully grounds the ball over the opposition try line.
Fouls		
Foul	Consensus	Total number of foul plays during the match.
- Free Kick	England Rugby	An individual player concedes a free kick.
- Penalty	England Rugby	An individual player concedes a penalty.
- Yellow Card	England Rugby (Modified)	A player is given a yellow card and sent to the sin bin for 10 minutes.
- Red Card	England Rugby (Modified)	A player is given a red card and is sent off the pitch for the remainder of the game.

3.5.4 Match Analysis Validation

One coder was used to analyse all of the matches within this thesis. To ensure that the coder was analysing matches correctly, they analysed a single match which had previously been analysed by an expert coder (> 10 years of experience). The coder was required to be within 10% of the expert coder for all key events (table 3.5), using the same process outlined below, before being allowed to collect data. This was done to ensure that they were at a standard set by an expert, before analysing the matches used within this thesis. However, the emphasis was placed on the post-coding validation. The focus for this was on validity and repeatability, due to the fact that there was a single coder.

Once the data collection had been completed, the match coding was validated by the same expert coder, who re-coded one match from each age group. The total count for key events was compared to the coder's analysis. The percentage that the coder was away from the expert coder was calculated, for both the number of events and time; alongside means for each event, age group and overall. When the number of contact or game events was less than 10 for both coders this was excluded from the validation, being removed from the mean calculations. This was done as anything other than complete agreement would have resulted in a disagreement of over 10%, due to the small sample size.

Key events and age groups were validated if the coder was less than 10% from the expert coder. Where agreement was over 10%, a decision was made on a case-by-case basis. All events at all age groups fell within the 10% limit, with the exception of penalties. Due to the quality of the footage, it was not always possible to see the referee hand signals and to distinguish between penalties and free kicks. To rectify this issue, penalties and free kicks were combined into "fouls".

Intra-rater reliability was also assessed. The coder re-analysed half of a game from each of the three age groups (>1 month from original analysis). The same method was used to validate their coding, using the percentage that they were away from their original analysis. The results can be seen in table 3.5.

Table 3.5: Match analysis validation.

Event	Under-13				Under-15				Under-18				Overall			
	CvE	**Decision**	**CvC**	**Decision**	**CvE**	**Decision**	**CvC**	**Decision**	**CvE**	**Decision**	**CvC**	**Decision**	**CvE**	**Decision**	**CvC**	**Decision**
Contact Events																
A. Collision	-	Exclude	-	Exclude	-	Exclude	-	Exclude	-	Exclude	-	Exclude	**-**	**Exclude**	**-**	**Exclude**
Maul	-	Exclude	-	Exclude	-	Exclude	-	Exclude	9.1%	Exclude	-	Exclude	**4.3%**	**Accept**	**0.0%**	**Accept**
Ruck	2.9%	Accept	0.0%	Accept	1.0%	Accept	6.1%	Accept	2.7%	Accept	0.0%	Accept	**2.4%**	**Accept**	**1.0%**	**Accept**
Scrum	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	5.9%	Accept	-	Exclude	**1.9%**	**Accept**	**0.0%**	**Accept**
Tackle	1.6%	Accept	3.0%	Accept	1.3%	Accept	1.9%	Accept	0.5%	Accept	3.8%	Accept	**0.4%**	**Accept**	**0.8%**	**Accept**
Game Events																
Clean Break	6.7%	Accept	-	Exclude	-	Exclude	-	Exclude	-	Exclude	-	Exclude	**3.4%**	**Accept**	**0.0%**	**Accept**
Kick	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%		5.8%	Accept	0.0%	Accept	**2.5%**	**Accept**	**0.0%**	**Accept**
Kick-Off	0.0%	Accept	-	Exclude	0.0%	Accept	-	Exclude	-	Exclude	-	Exclude	**0.0%**	**Accept**	**0.0%**	**Accept**
Lineout	-	Exclude	-	Exclude	0.0%	Accept	-	Exclude	5.3%	Accept	-	Exclude	**3.1%**	**Accept**	**6.7%**	**Accept**
Pass	0.8%	Accept	4.7%	Accept	2.2%	Accept	0.0%	Accept	1.4%	Accept	4.4%	Accept	**1.4%**	**Accept**	**3.6%**	**Accept**
Penalty	11.1%	>10%	-	Exclude	0.0%	Accept	0.0%	Accept	26.1%	>10%	0.0%	Accept	**14.3%**	**>10%**	**0.0%**	**Accept**
Scoring																
Conversion	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	**0.0%**	**Accept**	**0.0%**	**Accept**
Drop Goal	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	**0.0%**	**Accept**	**0.0%**	**Accept**
Penalty Kick	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	**0.0%**	**Accept**	**0.0%**	**Accept**
Try	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	0.0%	Accept	**0.0%**	**Accept**	**0.0%**	**Accept**
Timing																
BIP Time	5.8%	Accept	3.8%	Accept	1.3%	Accept	4.1%	Accept	3.7%	Accept	1.0%	Accept	**3.7%**	**Accept**	**2.1%**	**Accept**
Match Time	0.0%	Accept	0.1%	Accept	1.1%	Accept	0.1%	Accept	5.6%	Accept	0.0%	Accept	**2.0%**	**Accept**	**0.0%**	**Accept**
Overall	**2.1%**	**Accept**	**1.1%**	**Accept**	**0.5%**	**Accept**	**1.0%**	**Accept**	**4.7%**	**Accept**	**0.8%**	**Accept**	**2.5%**	**Accept**	**0.9%**	**Accept**

Note: CvE (Coder v Expert Validation; % from Expert); CvC (Coder Intra-Rater Reliability; % from original coding).

3.6 Tackle Analysis

This section lays the foundation for chapter six, focusing on the analysis of tackles and how this analysis was validated.

3.6.1 Tackle Coding Window

A tackle characteristic coding window (figure 3.2), for use within chapter six, was created; primarily using descriptors. These were used to add detail to the tackle categories which had been coded during the match analysis. An "adjust tackle" category was also included, so that an extra event could be added when there was more than one tackler.

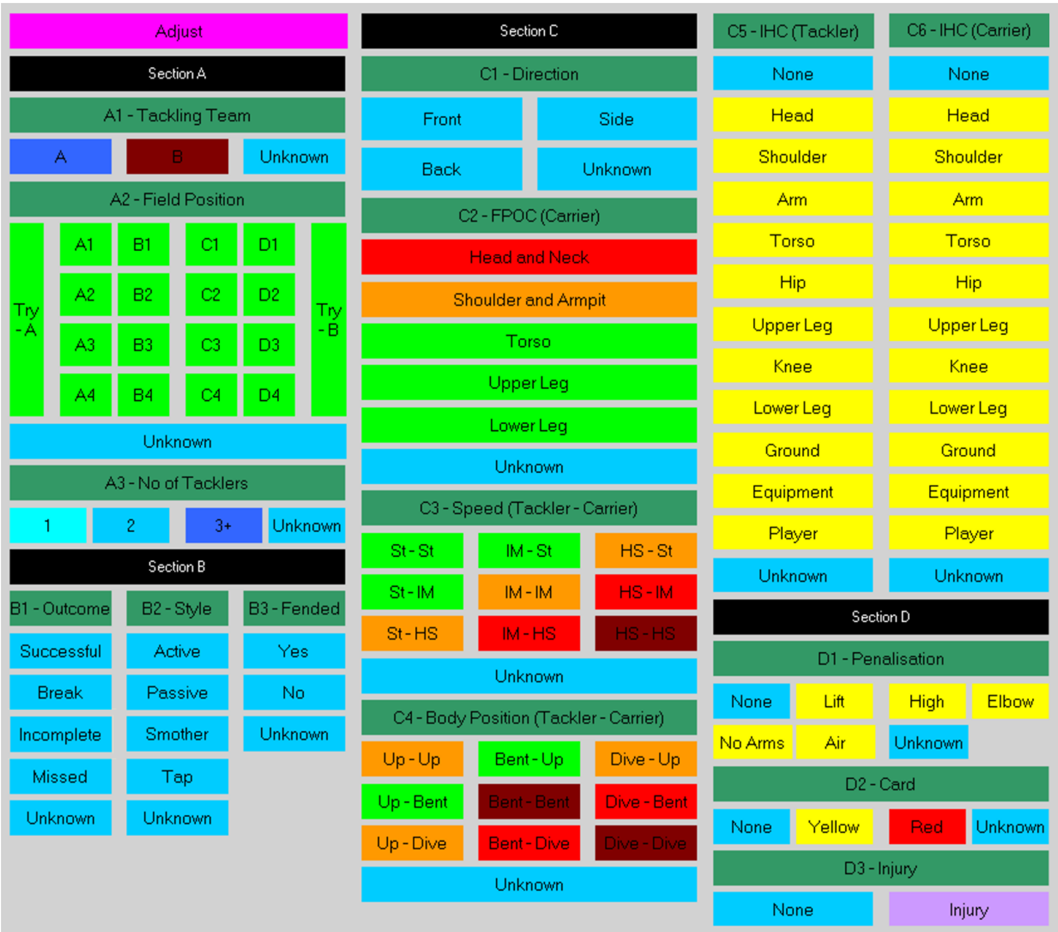

Figure 3.2: Nacsport tackle characteristic coding window.

Games which had previously been analysed for match events (chapter five) were loaded and tackle characteristics were then added to each tackle category using the descriptors on the coding window. When there was more than a single tackler, an "adjust tackle" category was input and the process was repeated, to capture the characteristics of further tacklers.

As was done for the match analysis coding window (figure 3.1), an injury button (descriptor) was included within the tackle analysis coding window. Suspected injuries or those requiring medical attention were flagged so that coders could follow up with schools, if required. This also meant that tackles which potentially resulted in injury could easily be identified, should this be required for future research.

Once the tackles within a match had been analysed, they were exported from the Nacsport software as an Excel file and cleaned. This included checking that there was no missing data and that each of the characteristics were in the correct column. Exported data files from each match were then merged into a master spreadsheet for analysis.

3.6.2 Variables

For the analysis of tackles, the same methodology for determining definitions as the match event analysis (section 3.5.3) was adopted. Alongside the consensus on a video analysis framework of descriptors and definitions by the rugby union video analysis consensus group (Hendricks et al., 2020), England Rugby's Tackle Trial Operational Definitions Manual (England Rugby, 2018a) was used to define tackle characteristics. Table 3.6 outlines the definitions and their origin for the analysis of tackles within this thesis. An unknown category was also included for each of the tackle characteristics.

Table 3.6: Tackle characteristic definitions and their origin.

Characteristic	Origin	Definition
Tackler		
Primary	England Rugby	The primary tackler in the tackle. Predominantly the 1st defender to make contact or the defender who makes the most significant contact.
Adjust	England Rugby	Any tackler(s) who joins the tackle (prior to the tackle being complete) once a primary tackle / contact has been made.
Field Position		
Vertical	Consensus	The field was divided into vertical sections between the two try-lines. A representing the area between the attacking team's 22m line and own try-line, B the area between attacking team's 22m line and half-way line, C the area between the opposition 22m line and half-way line and D representing the area between the opposition 22m and try-line.
Horizontal	Consensus	The field was divided into horizontal quadrants between the two touch lines with quadrant 1 representing the area furthest away from the camera, and quadrant 4 representing the area closest to the camera view.
Number of Tacklers		
1	Consensus (Modified)	One defender actively attempting to stop or impede the ball carrier (player carrying the ball) whether the ball carrier was brought to ground or not. Tacklers are counted until the ball carrier is brought to ground.
2	Consensus (Modified)	Two defenders actively attempting to stop or impede the ball carrier (player carrying the ball) whether the ball carrier was brought to ground or not. Tacklers are counted until the ball carrier is brought to ground.
>2	Consensus (Modified)	Three or more defenders actively attempting to stop or impede the ball carrier (player carrying the ball) whether the ball carrier was brought to ground or not. Tacklers are counted until the ball carrier is brought to ground.
Outcome		
Successful	Consensus (Modified)	When a tackle break does not occur, and either player goes to ground or the ball carrier is held up and cannot progress further, whether they offload the ball or not.
Tackle Break	Consensus	The ball carrier successfully penetrates the attempted tackle and continues to advance.
Incomplete	Original	The tackler makes contact, but actively decides not to complete the tackle. This is common after the ball is offloaded.
Unsuccessful (Missed)	Original	There is no meaningful contact and the tackler fails to tackle the ball carrier, thus allowing the ball carrier to advance during open play.
Style		
Active	Consensus (Modified)	First contact is with the tackler's shoulder, and the tackler drives or attempts to drive the ball carrier backwards towards the opposition try line.
Passive	Consensus (Modified)	The tackler does not drive or attempt to drive the ball carrier backwards towards the opposition try line.
Smother	Consensus	Tackler uses chest and wraps both arms around ball carrier.
Tap	Consensus	Tackler trips ball carrier with hand on lower limb below the knee.
Fended		
Yes	Consensus (Merged)	Ball carrier provided a light to moderate (eg, swat or slap technique) or strong (eg, push technique) fend.
No	Consensus	Ball carrier provided no fend.
Direction		
Front	Consensus (Modified)	Tackler makes contact in front of the ball carrier (315-0-45 degrees).
Side	Consensus (Modified)	Tackler makes contact with the ball carrier's side (315-225; 135-45 degrees).
Back	Consensus (Modified)	Tackler makes contact with the ball carrier's from behind (225-180-135 degrees).

Table 3.6 (Cont'd): Tackle characteristic definitions and their origin.

Characteristic	Origin	Definition
First Point of Contact		
Head & Neck	England Rugby	Initial contact is made on any part of the head or neck of the ball carrier by the tackler or adjust tackler.
Shoulder & Armpit	England Rugby	Initial tackle contact is made above the line of the armpit and below the top of the shoulders.
Torso	England Rugby	Initial contact is made on the torso - above the mid-point line of the hips and below the line of the armpits.
Upper Leg	England Rugby	Initial contact is made on the Upper leg - above the mid-point of the knee and below the mid-point of the hips.
Lower Leg	England Rugby	Initial contact is made on the Lower leg - from the foot unto the mid-point of the knee.
Speed		
Static	England Rugby (World Rugby)	If a player has his feet planted in the final moments before contact, then he is static.
In Motion	England Rugby	If a player is in motion (walking / jogging) but not at 'high speed' going into contact.
High Speed	England Rugby (World Rugby)	If a player is at fast pace or sprinting.
Body Position		
Upright	England Rugby (Modified)	The tackler / carrier are upright (no bend at the waist / hips) at the point of contact, maybe slightly bent at knees (if a line is drawn outwards from the chest, it would not intersect the floor).
Bent	Original	The tackler / carrier are bent at the waist at the point of contact (if a line is drawn outwards from the chest, it would intersect the floor).
Diving	England Rugby	The tackler / carrier is the process of diving at the point of contact.
Head Contact		
General	England Rugby	Any clear head contact occurring in the tackle to either the carrier or tacklers. If there is no head contact made, no head contact must be coded to the relevant player. Every tackler and carrier should have either a head to body part code or a no head contact code. Head to body part codes are listed below.
Categories	England Rugby (Modified), Consensus (Modified)	No Head Contact Head To Head Head To Shoulder Head To Arm Head To Torso Head To Hip Head To Upper Leg Head To Knee Head To Lower Leg Head To Ground Head To Equipment Head To Player
Equipment	England Rugby	Head to equipment includes any contact with post protectors, flags or the ball.
Player	Original	The ball carrier's head makes contact with a player other than the tackler.
Penalisation		
Lift	England Rugby	Penalised by the referee for allowing the ball carrier to go beyond horizontal.
High	England Rugby	Penalised by the referee for contact being high.
Elbow	England Rugby	A tackler is penalised by the referee for illegally using his elbow / forearm.
No Arms	England Rugby (Modified)	A tackler is penalised by the referee as shoulder only used to make the tackle - no use of arms.
Air	England Rugby	Penalised by the referee for a defender making contact with the carrier in the air.

3.6.3 Tackle Analysis Validation

Two coders were used for the analysis of tackles within this thesis. Before any analysis was conducted both coders were required to code 30 tackles which had previously been coded by an expert coder (>10 years of experience). They were required to achieve 90% agreement with the expert coder for each characteristic before being allowed to collect data. This was done to ensure that they were at a standard set by an expert, before analysing the tackles used within this thesis. However, the emphasis was placed on the post-coding validation. The focus for this was on reliability and repeatability, due to the fact that there were two experienced coders.

Once the data collection had been completed, both coders analysed 60 tackles from each age group and inter-rater reliability was assessed using Cohen's kappa (Cohen, 1960). An intra-rater analysis was also completed, with Coder 1 and Coder 2 re-analysing 30 tackles at each age group (>1 month from original analysis). Where p_o is the observed accuracy and p_e is expected accuracy, the formula for calculating kappa scores is:

$$k = \frac{p_o - p_e}{1 - p_e}$$

The kappa score was calculated for each tackle characteristic and a mean was taken for each age group and overall. When there was 100% agreement on a single characteristic, the kappa statistic could not be calculated, so this was given a score of 1. The data was then interpreted based on Cohen's (1960) original suggestion (table 3.7), which is commonly used and was endorsed by Landis and Koch (1977). A kappa of >0.8 was set for validation, to ensure that any coding was "almost perfect". More recently, McHugh (2012) laid out stricter criteria, but would still rate scores of >0.8 as "strong".

Table 3.7: Interpretation of the kappa statistic.

Cohen (1960) / Landis & Koch (1977)		**McHugh (2012)**	
Kappa Score	**Interpretation**	**Kappa Score**	**Interpretation**
0-0.20	Slight	0-0.20	None
0.21-0.40	Fair	0.21-0.39	Minimal
0.41-0.60	Moderate	0.40-0.59	Weak
0.61-0.80	Substantial	0.60-0.79	Moderate
0.81-1	Almost Perfect	0.80-0.90	Strong
		0.91-1	Almost Perfect

The U13 (0.8), U15 (0.8) and U18 (0.74) kappa scores fell just short of "almost perfect", yet the overall kappa score for inter-rater reliability was 0.8, deemed "substantial" and "strong". For individual characteristics which fell below the required kappa score, it was checked to see whether the overall score for that characteristic was affected. If the agreement was "substantial" no further investigation was conducted. Where the agreement was "moderate" or below, this was investigated further. This was the case for direction, ball carrier head contact and penalisation (table 3.8).

For direction, there was agreement between Coder 1 and Coder 2 in 143/180 cases. The only disagreements were where one Coder considered a tackle a "side" tackle and the other considered it a "front" or "back" tackle. It was decided that this characteristic would be included as there was 79% agreement, but the kappa score should be considered when interpreting the results for this characteristic. For ball carrier head contact, there was agreement in 148/180 (82%) cases. Whilst head contact will be described within chapter six, it was decided that head contact, both for the ball carrier and tackler, would be considered "yes" or "no" for statistical analysis, based on the kappa score. For penalisation, there was 99% accuracy (178/180). When calculating kappa scores for characteristics with minimal variability, mistakes or disagreements cause the score to drop significantly. Whilst this is the case, it was decided that penalisation would be described within the chapter but would not be included within the statistical analysis.

It was also decided that field position would be split into "length" and "width" of the pitch, to increase power during statistical analysis. Both for speed and body position, the ball carrier and tackler were coded together but it was decided that the characteristics for the ball carrier and tackler would be split up. Thus, it is expected that the true kappa score of these characteristics is higher than stated in table 3.8. This would also be the case for head contact after being re-coded into a binary outcome.

Tackling team and cards were not included within the statistical analysis. Tackling team was coded to ensure that an even spread (±5%) of tackles from each team was analysed and to help ensure coders were correctly identifying the tackler and ball carrier during validation. Cards are only described within chapter 6 due to the low number which were identified. It was also decided that injuries would be excluded entirely, as it could not be confirmed that they were 24-hour time-loss injuries.

Table 3.8: Tackle analysis validation.

Characteristic	Under-13						Under-15						Under-18						Overall					
	1v2		1v1		2v2		1v2		1v1		2v2		1v2		1v1		2v2		1v2		1v1		2v2	
	k	Int	k	Int	k	Int	k	Int	k	Int	k	Int	k	Int	k	Int	k	Int	k	Int	k	Int	k	Int
Tackling Team	1.00	A	1.00	A	1.00	A	0.97	A	1.00	A	1.00	A	0.97	A	1.00	A	1.00	A	0.98	A	1.00	A	1.00	A
Field Position	0.94	A	0.92	A	0.92	A	0.93	A	0.96	A	0.93	A	0.83	A	0.92	A	0.96	A	0.90	A	0.94	A	0.94	A
No of Tacklers	0.74	B	0.87	A	0.79	B	0.73	B	0.84	A	0.46	C	0.92	A	0.90	A	1.00	A	0.82	A	0.88	A	0.84	A
Outcome	0.91	A	0.93	A	0.78	B	0.96	A	0.92	A	0.93	A	1.00	A	1.00	A	0.79	B	0.94	A	0.94	A	0.85	A
Style	1.00	A	0.73	B	0.64	B	0.78	B	0.76	B	0.63	B	0.90	A	0.48	C	1.00	A	0.88	A	0.74	B	0.72	B
Fended	0.68	B	1.00	A	1.00	A	0.55	C	1.00	A	1.00	A	0.88	A	0.71	B	1.00	A	0.71	B	0.89	A	1.00	A
Direction	0.53	C	0.74	B	0.77	B	0.71	B	0.79	B	1.00	A	0.45	C	0.84	A	0.91	A	0.56	C	0.81	A	0.90	A
FPOC	0.77	B	0.81	A	0.59	C	0.81	A	0.91	A	0.90	A	0.61	C	0.95	A	1.00	A	0.74	B	0.89	A	0.84	A
Speed	0.91	A	0.77	B	0.82	A	0.64	B	0.85	A	0.84	A	0.74	B	0.90	A	0.82	A	0.77	B	0.85	A	0.84	A
Body Position	0.85	A	0.95	A	0.80	B	0.73	B	0.91	A	0.95	A	0.71	B	0.77	B	0.95	A	0.77	B	0.88	A	0.91	A
Tackler HC	0.92	A	0.91	A	0.62	B	0.77	B	0.91	A	0.80	B	0.61	B	0.84	A	0.90	A	0.78	B	0.89	A	0.78	B
Carrier HC	0.72	B	1.00	A	0.85	A	0.45	C	0.81	B	0.79	B	0.55	C	0.87	A	0.90	A	0.59	C	0.91	A	0.86	A
Penalisation	0.00	E	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	0.00	E	1.00	A	1.00	A	0.50	C	1.00	A	1.00	A
Card	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A
Injury	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A	1.00	A
Overall	**0.80**	B	**0.91**	A	**0.84**	A	**0.80**	B	**0.91**	A	**0.88**	A	**0.74**	B	**0.88**	A	**0.95**	A	**0.80**	B	**0.91**	A	**0.90**	A

Note: 1v2 (Coder 1 v Coder 2 Inter-Rater Reliability); 1v1 (Coder 1 Intra-Rater Reliability); 2v2 (Coder 2 Intra-Rater Reliability). Interpretations (Int) were coded as: A: Almost Perfect (0.81-1); B: Substantial (0.61-0.80); C: Moderate (0.41-0.60); D: Fair (0.21-0.40); E: Slight (0-0.20).

3.7 Statistical Analysis

The analysis for each of the study chapters was completed separately, primarily using Microsoft Excel and IBM SPSS Statistics 25. The specific analysis used for each study is described within each chapter (chapters four, five and six).

CHAPTER FOUR

EPIDEMIOLOGY OF INJURIES IN ENGLISH SCHOOLBOY RUGBY UNION

This study describes the incidence, severity and burden of injuries in schoolboy rugby union in England, across three age groups: under-13 (U13), under-15 (U15) and under-18 (U18). Overall, data from 574 24-hour time-loss injuries and 18,485 player-hours of match exposure was collected from 66 teams in the 2017/18-2019/20 seasons. Injury incidence (injuries / 1000h) and burden (days lost / 1000h) were calculated for each age group and were compared using Z scores. The U18 age group had a significantly higher injury incidence (34.6 injuries / 1000h) and burden (941 days / 1000h) than both the U13 (incidence: 20.7 injuries / 1000h; burden: 477 days / 1000h) and U15 (incidence: 24.6 injuries / 1000h; burden: 602 days / 1000h) age groups, but no significant differences were found between the U13 and U15 age groups. Contact events accounted for 87-88% of known injury events at each age group, with the tackle responsible for 52% (U13), 48% (U15) and 62% (U18) of all injuries. Concussion was the most common injury type in all age groups (U13: 4.8 injuries / 1000h; U15: 6.4 injuries / 1000h; U18: 9.2 injuries / 1000h), but the incidence was not significantly different between age groups. Injury incidence and burden is higher at U18 than at U13 and U15. Concussions and the tackle are priority areas at all age groups and should be the focus of future interventions.

4.1 Introduction

Rugby union is one of the most popular sports played by young people in England (Sport England, 2016), but has been under increasing scrutiny due to its high risk of injury (Carter, 2015). At the professional level, rugby has been researched extensively and has one of the highest injury incidences of all team sports (Williams et al., 2013); however, due to differences in player physique, game speed, laws of the game and length of play, this data cannot not be applied to the youth population (Bleakley et al., 2011).

Studies have described injuries in youth rugby populations, with Palmer-Green et al. (2013) reporting a match injury incidence of 35 injuries / 1000h for under-18 schoolboy rugby players in England. A similar injury incidence for schoolboy rugby players was found by Archbold et al. (2017) and Barden and Stokes (2018), with 29 injuries / 1000h (under-18, Ireland) and 34 injuries / 1000h (sub-elite under-19, England) respectively. All three studies found that, within the same age group, a higher playing level was associated with an increased risk of injury.

Much of the research in school settings has focused on under-18 players, with very little attention being paid to younger age groups. Hislop et al. (2017) reported an injury incidence of 30 injuries / 1000h in schoolboy rugby players aged 14-18 in England, but the incidence rates of individual age groups were not described. In New Zealand, Quarrie et al. (2020) investigated rugby-related insurance claims, finding that 7-12 year-old players had an 9% chance of making a claim due to injury during a season, compared with a 36% chance at 13-17 years old. A systematic review of rugby related injuries also found a clear association between increasing age and a higher injury incidence, but there were wide variations in the definitions and methodologies that were used (Bleakley et al., 2011). Contradicting most other research in this area, under-13 (23.9 injuries / 1000h) and under-16 (22.2 injuries / 1000h) players were found to have a higher injury incidence than under-18 players (17.2 injuries / 1000h) in South African youth rugby tournaments spanning 2011 to 2016 (Sewry et al., 2018). The injury definition, "any physical complaint", may have been responsible for this, as under-13 players may be less robust, or able to deal with the demands of contact, than older players and more likely to report an injury.

Given that injury incidence has been shown to differ with age, it is important that each population is investigated individually to inform population-specific injury prevention strategies. This study will describe the incidence, severity and burden of injuries in under-13 (U13), under-15 (U15) and under-18 (U18) schoolboy rugby union players in England.

4.2 Methods

4.2.1 Study Design & Setting

This was a prospective cohort study, describing rugby-related injuries in an English secondary school setting.

4.2.2 Study Size

In total, 102 team-seasons of data were collected over three seasons, from 66 different teams, across 35 schools (table 4.1).

Table 4.1: Schools and teams providing epidemiological data.

	Under-13		Under-15		Under-18		Overall	
Season	**Schools, n**	**Teams, n**	**Schools, n**	**Teams, n**	**Schools, n**	**Teams, n**	**Schools, n**	**Teams, n**
2017/18	8	9	11	12	17	18	19	39
2018/19	3	3	9	9	14	15	16	27
2019/20	4	4	10	10	20	22	21	36
Overall	12	13	20	20	30	33	35	66

4.2.3 Participants

This study was conducted over three school rugby seasons, from September 2017 to April 2020. Each season ran from September until April for U13 teams and from September until December for U15 and U18 teams, with most games being played in October and November.

Data for this study was collected as part of England Rugby's (the national governing body for rugby union in England) Youth Rugby Injury Surveillance Project, which had previously run from 2006-2008 and from 2013-2016. An existing database of school contact details (n=85) was used for recruitment in the first season and was expanded with additional school contacts for the second (n=164) and third (n=278) seasons (table 3.1). Schools in the database were contacted four months before the start of the season and asked to solicit participation. There was no limit to the number of teams each school could include, but only boys' teams in the U13, U15 and U18 age groups were eligible.

Ethical approval for the study was obtained from the Research Ethics Approval Committee for Health (REACH) at the University of Bath. Before any data was collected, player (APPENDIX E), parent (APPENDIX F) and staff (ANNEX G) information sheets, player assent forms (APPENDIX H) and parental (APPENDIX I) and staff (APPENDIX J) consent forms were sent electronically, using Bristol Online Surveys (Online Surveys, 2021). Non-consent from an individual player would have resulted in removal from the study, however this was not necessary.

4.2.4 Variables

This study was designed in line with the Consensus Statement on injury definitions and data collection procedures for studies of injury in rugby union (Fuller et al., 2007b). A 24-hour time-loss definition was used, where injuries were recorded if a player was unable to take a full part in training or match play for more than 24 hours from midnight at the end of the day that the injury was sustained. Match exposure was classified as play between teams from different schools and was calculated using the formula:

Exposure (Player-Hours) = Match Length (Minutes) x Number of Players (n) / 60

U13 games lasted 50 minutes, U15 games lasted 60 minutes and U18 games lasted 70 minutes. The clock does not stop in youth matches, meaning that all matches should have lasted the allocated time. U15 and U18 matches involve 15 players per team and are played on a full-size pitch (maximum: 100x70 metres). U13 matches involve 13 players (six forwards, instead of eight, as per older age groups) and are played on a smaller pitch (maximum: 90x60 metres).

4.2.5 Data Collection

A nominated project co-ordinator at each school, normally a coach or physiotherapist, was responsible for collecting data on a spreadsheet (APPENDIX B) that captured information on the school (contact details, address), team (squad list, age group), their matches (date, match length, opponent, outcome) and match injuries (date, return to play date, match quarter, playing position, event, site, type). If schools preferred to use paper forms (APPENDICES C & D) to collect the same data, these were posted to the school with a return envelope. Project co-ordinators were reminded to return data every six weeks and at the end of each season. This was done by uploading their spreadsheet onto a secure University server, using a link sent to them, or by posting their paper forms to the research team. If sent by post, no information which could be used to identify players was sent.

Both injuries and matches were tracked on a master spreadsheet, with injuries being checked to ensure that they fell within the period of match data provided by the team. If they did not, the additional exposure was requested, given that this would have highlighted that additional matches were being played. If this was not provided, the injury was removed. If data was missing, this was requested from the school. If the school was unsure of the answer or did not respond following a second attempt to follow up, this data was marked as "unknown". If no (or estimated) time-loss was provided, these injuries were used within the incidence calculations, providing the research team was sure that these were 24 hour time-loss injuries, but not within the severity or burden calculations (n=110, 19%).

4.2.6 Statistical Analysis

Injury incidence was defined as the number of injuries per 1000 player-hours (injuries / 1000h). Injury severity was defined as the number of full days that elapsed from the date of injury until the date of the player's return to full participation in team training and availability for match selection. Injury burden was calculated by multiplying the mean severity by injury incidence (Fuller, 2018), giving days lost per 1000 player-hours (days lost / 1000h).

Data received from schools was entered into a master spreadsheet in Microsoft Excel (APPENDIX B). Injury sites were grouped into regions: head & neck (head, neck), upper limb (shoulder, upper arm, elbow, forearm, wrist & hand), torso (chest, trunk & abdomen, thoracic spine, lumbar spine) and lower limb (hip & groin, pelvis & buttock, thigh, knee, lower leg, ankle, foot).

Analysis was conducted in Microsoft Excel and on IBM SPSS Statistics 25. Injury incidence and burden were calculated with 95% Poisson Confidence Intervals. To allow for comparison with other studies, a 7-day time-loss injury incidence for the U13, U15 and U18 age groups was also calculated. The log of the rate ratio was used to calculate Z scores, with the assumption of normality of the data. These were used to compare injury incidence and burden within (regions, events, playing positions and match periods) and across (U13 v U15; U13 v U18; U15 v U18) age groups. When making three or less comparisons a Bonferroni correction (Bonferroni, 1936) was used to minimise the chance of Type 1 error. Where more than three comparisons were made, a Holm-Bonferroni correction (Holm, 1979; Wright, 1992) was used to minimise the risk of Type 2 error. Concussions, which had been collected as nerve injuries and marked as concussions, were investigated using the same method. This was done both within and across age groups for events and playing position.

Mean severity was calculated with 95% Confidence Intervals and median severity with an Inter-Quartile Range (IQR). A two-tailed independent t-test with a Bonferroni correction (Bonferroni, 1936) was used to determine whether there were significant differences in the mean severity of injury. Results where $p<0.05$ were considered significant.

4.3 Results

In total, 18,485 match player-hours and 574 match injuries were collected (table 4.2). The U18 age group accounted for 67% (12,393 player-hours) of the total exposure and 75% (429 injuries) of the injuries collected within the study [U13: 1,259 player-hours (7%), 26 injuries (4%); U15: 4,834 player-hours (26%), 119 injuries (21%)].

4.3.1 Incidence

The U18 age group had a significantly higher injury incidence (34.6 injuries / 1000h, 95% CI=31.5,38.1) than both the U13 (20.7 injuries / 1000h, 95% CI=14.1,30.3, p=0.03) and U15 (24.6 injuries / 1000h, 95% CI=20.6,29.5, p<0.01) age groups, but no significant differences were found between U13 and U15 (table 4.2). The incidence reflects one injury per team every 4.5 matches at U13, 2.7 matches at U15 and 1.7 matches at U18. The incidence for 7-day time-loss injuries was 15.1 injuries / 1000h (n=19; 95% CI=9.6,23.7) at U13, 14.5 injuries / 1000h (n=70; 95% CI=11.5,18.3) at U15 and 22.2 injuries / 1000h (n=275; 95% CI=19.7,25.0) at U18.

4.3.2 Severity

There were no significant differences in mean severity of injuries between age groups (table 4.2). The median severity (U13: 20 days; U15: 20 days; U18: 22 days) was less than the mean severity (U13: 23 days; U15: 25 days; U18: 27 days). The most common severity category was 8-28 days for all age groups (U13=38%; U15=35%; U18=35%) (table 4.3).

4.3.3 Burden

Burden in the U18 age group (941 days / 1000h, 95% CI=856,1035) was significantly higher than that for both the U13 (477 days / 1000h, 95% CI=325,701, p<0.01) and U15 (602 days / 1000h, 95% CI=503,721, p<0.01) age groups; there were no significant differences between U13 and U15 (table 4.2).

Table 4.2: An overview of the epidemiological data collected and overall injury incidence, severity and burden.

	Under-13	**Under-15**	**Under-18**	**Overall**
Injuries, n	26	119	429	574
Exposure, player match-hours	1259	4834	12393	18485
Matches, n	117	325	706	1148
Incidence, injuries/1000h (95% CI)	20.7 (14.1-30.3)	24.6 (20.6-29.5)	34.6 (31.5-38.1)[35]	31.1 (28.6-33.7)
Severity, mean days (95% CI)	23 (14-32)	25 (20-29)	27 (24-30)	26 (24-29)
Severity, median days (IQR)	20 (6-35)	20 (7-34)	22 (10-34)	22 (9-34)
Burden, days/1000h (95% CI)	477 (325-701)	602 (503-721)	941 (856-1035)[35]	820 (755-890)

Note: Bold events were compared across age groups. Significantly greater than is represented by: 3: U13; 5: U15.

Table 4.3: Injury severity categories.

Days	**Under-13**		**Under-15**		**Under-18**		**Overall**	
Days	**n (%)**	**Incidence, injuries/1000h (95% CI)**	**n (%)**	**Incidence, injuries/1000h (95% CI)**	**n (%)**	**Incidence, injuries/1000h (95% CI)**	**n (%)**	**Incidence, injuries/1000h (95% CI)**
1-7	7 (27)	5.6 (2.7-11.7)	25 (21)	5.2 (3.5-7.7)	71 (17)	5.7 (4.5-7.2)	103 (18)	5.6 (4.6-6.8)
8-28	10 (38)	7.9 (4.3-14.8)	42 (35)	8.7 (6.4-11.8)	151 (35)	12.2 (10.4-14.3)	203 (35)	11.0 (9.6-12.6)
29-84	9 (35)	7.1 (3.7-13.7)	23 (19)	4.8 (3.2-7.2)	110 (26)	8.9 (7.4-10.7)	142 (25)	7.7 (6.5-9.1)
>84	0	-	5 (4)	1.0 (0.4-2.5)	11 (3)	0.9 (0.5-1.6)	16 (3)	0.9 (0.5-1.4)
Unknown	0	-	24 (20)	-	86 (20)	-	110 (19)	-

4.3.4 Type

At U13, the most common types of injury were nerve injury (n=7; incidence: 5.6 injuries / 1000h, 95% CI=2.7,11.7; burden: 129 days / 1000h, 95% CI= 62,272), bruising / haematoma (n=5; incidence: 4.0 injuries / 1000h, 95% CI=1.7,9.5; burden: 57 / 1000h, 95% CI= 24,137), fracture (n=3; incidence: 2.4 injuries / 1000h, 95% CI=0.8,7.4; burden: 144 days / 1000h, 95% CI= 46,446) and muscle injury (n=3; incidence: 2.4 injuries / 1000h, 95% CI=0.8,7.4; burden: 34 days / 1000h, 95% CI= 11,106) (APPENDIX M).

At U15, the most common types of injury were nerve injury (n=31; incidence: 6.4 injuries / 1000h, 95% CI=4.5,9.1; burden: 162 days / 1000h, 95% CI= 114,230), fracture (n=20; incidence: 4.1 injuries / 1000h, 95% CI=2.7,6.4; burden: 271 days / 1000h, 95% CI= 175,421) and muscle injury (n=14; incidence: 2.9 injuries / 1000h, 95% CI=1.7,4.9; burden: 30 days / 1000h, 95% CI= 18,51).

At U18, the most common types of injury were nerve injury (n=120; incidence: 9.7 injuries / 1000h, 95% CI=8.1,11.6; burden: 284 days / 1000h, 95% CI= 238,340), ligament injury (n=76; incidence: 6.1 injuries / 1000h, 95% CI=4.9,7.7; burden: 204 days / 1000h, 95% CI= 163,256) and muscle injury (n=50; incidence: 4.0 injuries / 1000h, 95% CI=3.1,5.3; burden: 71 days / 1000h, 95% CI= 54,94).

4.3.5 Site

At U13, the most common injury sites were the head (n=6; incidence: 4.8 injuries / 1000h, 95% CI=2.1,10.6; burden: 125 days / 1000h, 95% CI= 56,278), knee (n=6; incidence: 4.8 injuries / 1000h, 95% CI=2.1,10.6; burden: 66 days / 1000h, 95% CI= 30,147) and shoulder (n=4; incidence: 3.2 injuries / 1000h, 95% CI=1.2,8.5; burden: 76 days / 1000h, 95% CI= 29,203) (APPENDIX N).

At U15, the most common injury sites were the head (n=41; incidence: 8.5 injuries / 1000h, 95% CI=6.2,11.5; burden: 197 days / 1000h, 95% CI= 145,265), shoulder (n=17; incidence: 2.9 injuries / 1000h, 95% CI=1.7,4.9; burden: 97 days / 1000h, 95% CI= 57,163) and wrist and hand (n=12; incidence: 3.2 injuries / 1000h, 95% CI=2.2,5.7; burden: 74 days / 1000h, 95% CI= 46,119).

At U18, the most common injury sites were the head (n=148; incidence: 11.9 injuries / 1000h, 95% CI=10.2,14.0; burden: 296 days / 1000h, 95% CI= 252,348), shoulder (n=52; incidence: 4.2 injuries / 1000h, 95% CI=3.3,5.5; burden: 133 days / 1000h, 95% CI= 101,174) and ankle (n=47; incidence: 3.8 injuries / 1000h, 95% CI=2.8,5.0; burden: 143 days / 1000h, 95% CI= 107,190).

4.3.6 Region

At U18, both the head & neck (13.1 injuries / 1000h, 95% CI=-11.2,15.2) and lower limb (12.2 injuries / 1000h, 95% CI=10.4,14.3) had a significantly higher injury incidence than the upper limb (7.8 injuries / 1000h, 95% CI=6.4,9.6, $p<0.01$) and trunk (1.1 injuries / 1000h, 95% CI=0.7,1.9, $p<0.01$). There were no significant differences in the incidence of head & neck injuries across age groups, although burden was significantly higher at U18 (322 days / 1000h, 95% CI=276,376) than U15 (203 days / 1000h, 95% CI=152,272, p=0.02). When lower limb injuries were compared across age groups, U18 incidence (12.2 injuries / 1000h, 95% CI=10.4,14.3) and burden (330 days / 1000h, 95% CI=281,387) were significantly higher than that seen at U15 (incidence: 6.2 injuries / 1000h, 95% CI=4.3,8.9, p<0.01; burden: 149 days / 1000h, 95% CI=104,213, p<0.01) (table 4.4).

4.3.7 Event

Contact events accounted for 87% (n=20), 88% (n=93) and 87% (n=324) of known injury types at U13, U15 and U18, respectively, with the tackle responsible for 52% (U13), 48% (U15) and 62% (U18) of all injuries. The tackle had a significantly higher injury incidence at U18 (18.7 injuries / 1000h, 95% CI=16.5,21.3) than at U15 (10.6 injuries / 1000h, 95% CI=8.0,13.9, p<0.01). The burden of tackle injuries was also significantly higher at U18 (637 days / 1000h, 95% CI=560,725) than at U13 (294 days / 1000h, 95% CI=167,518, p=0.03) and U15 (352 days / 1000h, 95% CI=267,463, p<0.01) (table 4.4).

At U13 there were no significant differences between the injury incidence of different game events, however tackle burden (294 days / 1000h, 95% CI=167,518) was significantly higher than the burden of all other events (p<0.05). At U15 the tackle had a significantly higher injury incidence (10.6 injuries / 1000h, 95% CI=8.0,13.9, p<0.01) and burden (352 days / 1000h, 95% CI=267,463, p<0.01) than all other events. This was also the case at U18, with the tackle having a significantly higher injury incidence (18.7 injuries / 1000h, 95% CI=16.5,21.3, p<0.01) and burden (637 days / 1000h, 95% CI=560,725, p<0.01) than all other events. At U18, tackling injury incidence (10.7 injuries / 1000h, 95% CI=9.1,12.7) was significantly higher than that of injuries caused whilst being tackled (8.0 injuries / 1000h, 95% CI=6.6,9.7, p=0.03).

3.4.8 Playing Position

There were no significant differences between the injury incidence or burden for forwards or backs within any age group. The only significant finding in relation to playing position was that U18 forwards had a higher burden (911 days / 1000h, 95% CI=798,1041) than that of U15 forwards (559 days / 1000h, 95% CI=434,721) (p<0.01) (table 4.4).

3.4.9 Match Period

At both U15 ($p<0.01$) and U18 ($p=0.02$), Q1 (U15: 8.3 injuries / 1000h, 95% CI=4.5,15.4; U18: 17.4 injuries / 1000h, 95% CI=13.3,22.8) had a significantly lower injury incidence than Q3 (U15: 29.0 injuries / 1000h, 95% CI=20.8,40.3; U18: 29.0 injuries / 1000h, 95% CI=23.6,35.7). At U15 the incidence and burden were higher ($p<0.01$) in the second half (incidence: 25.2 injuries / 1000h, 95% CI=19.6,32.4; burden: 563 days / 1000h, 95% CI=438,724) than in the first (incidence: 12.8 injuries / 1000h, 95% CI=9.0,18.2; burden: 298 days / 1000h, 95% CI=210,424) (table 4.4).

Table 4.4 Incidence, severity and burden for injury region, event, playing position and match period.

	Under-13				Under-15				Under-18				Overall			
	n	**Incidence, injuries/1000h (95% CI)**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI)**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**
Region																
Head & Neck	7	5.6 (2.7-11.7)	23 (6-40)	128 (61-268)	45	9.3 (7.0-12.5)^{T}	22 (15-28)	203 (152-272)^{T}	162	13.1 (11.2-15.2)^{TU}	25 (21-29)	322 (276-376)^{5T}	214	11.6 (10.1-13.2)	24 (20-27)	277 (242-317)
Upper Limb	7	5.6 (2.7-11.7)	29 (8-51)	164 (78-343)	35	7.2 (5.2-10.1)^{T}	28 (17-40)	205 (148-286)^{T}	97	7.8 (6.4-9.6)^{T}	34 (26-41)	262 (215-320)^{T}	139	7.5 (6.4-8.9)	32 (26-38)	241 (204-285)
Trunk	2	-	-	-	8	1.7 (0.8-3.3)	28 (8-47)	46 (23-91)	14	1.1 (0.7-1.9)	17 (7-26)	19 (11-32)	24	1.3 (0.9-1.9)	23 (13-33)	30 (20-44)
Lower Limb	10	7.9 (4.3-14.8)	15 (6-24)	118 (63-219)	30	6.2 (4.3-8.9)^{T}	24 (14-34)	149 (104-213)^{T}	151	12.2 (10.4-14.3)^{5TU}	27 (22-32)	330 (281-387)^{35T}	191	10.3 (9.0-11.9)	26 (22-30)	267 (231-307)
Unknown	0	-	-	-	1	-	-	-	5	-	-	-	6	-	-	-
Event																
Tackle	12	9.5 (5.4-16.8)	31 (13-38)	294 (167-518)^{AMNRS}	51	10.6 (8.0-13.9)^{AMNORS}	26 (18-33)	352 (267-463)^{AMNORS}	232	18.7 (16.5-21.3)^{5ALMNORS}	30 (26-34)	637 (560-725)^{35ALMNORS}	295	16.0 (14.2-17.9)	29 (26-33)	466 (415-522)
-Tackling	8	6.4 (3.2-12.7)	30 (9-51)	192 (96-384)	26	5.4 (3.7-7.9)	23 (14-32)	173 (118-255)	133	10.7 (9.1-12.7)^{5K}	29 (23-34)	366 (309-434)^{5}	167	9.0 (7.8-10.5)	28 (23-32)	252 (217-294)
-Tackled	4	3.2 (1.2-8.5)	32 (1-63)	102 (38-271)	25	5.2 (3.5-7.7)	29 (16-42)	219 (148-324)	99	8.0 (6.6-9.7)	31 (25-38)	305 (250-371)	128	6.9 (5.8-8.2)	31 (25-37)	214 (180-255)
Ruck	3	2.4 (0.8-7.4)	15 (0-33)	37 (12-113)	19	3.9 (2.5-6.2)	26 (13-38)	101 (64-158)^{MS}	45	3.6 (2.7-4.9)^{LMS}	27 (18-35)	129 (96-172)^{MS}	67	3.6 (2.9-4.6)	26 (19-33)	94 (74-119)
A.Collision	3	2.4 (0.8-7.4)	17 (0-37)	41 (13-128)	18	3.7 (2.3-5.9)	27 (12-41)	99 (63-158)^{MS}	34	2.7 (2.0-3.8)^{LMS}	25 (15-34)	93 (67-130)^{MS}	55	3.0 (2.3-3.9)	25 (17-32)	74 (57-96)
Other	0	-	-	-	4	0.8 (0.3-2.2)	23 (0-50)	41 (15-110)^{M}	24	1.9 (1.3-2.9)^{LMS}	30 (17-44)	85 (57-127)^{MS}	28	1.5 (1.0-2.2)	30 (17-42)	45 (31-65)
Running	3	2.4 (0.8-7.4)	10 (0-21)	23 (7-71)	9	1.9 (1.0-3.6)	24 (5-43)	44 (23-85)^{MS}	24	1.9 (1.3-2.9)^{LMS}	26 (14-38)	74 (50-111)^{MS}	36	1.9 (1.4-2.7)	24 (15-33)	47 (34-65)
Scrum	1	-	-	-	4	0.8 (0.3-2.2)	5 (0-9)	7 (3-20)	6	0.5 (0.2-1.1)	8 (1-15)	7 (3-16)	11	0.6 (0.3-1.1)	8 (3-12)	4 (2-8)
Maul	1	-	-	-	1	-	-	-	5	0.4 (0.2-1.0)	22 (2-37)	15 (6-36)^{5}	7	0.4 (0.2-0.8)	16 (4-28)	6 (3-13)
Lineout	0	-	-	-	0	-	-	-	2	-	-	-	2	-	-	
Unknown	3	-	-	-	13	-	-	-	57	-	-	-	73	-	-	-
Playing Position																
Forwards	14	24.1 (14.3-40.7)	21 (10-32)	501 (297-846)	60	23.3 (18.1-30.0)	24 (17-31)	559 (434-721)	217	32.8 (28.7-37.5)	28 (24-32)	911 (798-1041)^{5}	291	15.7 (14.0-17.7)	27 (23-30)	418 (373-469)
Backs	12	17.7 (10.1-31.2)	26 (11-40)	457 (260-805)	56	24.8 (19.1-32.3)	26 (18.34)	649 (500-843)	179	31.0 (25.6-35.8)	28 (24-33)	875 (756-1013)	247	13.4 (11.8-15.1)	28 (24-32)	370 (327-419)
Unknown	0	-	-	-	3	-	-	-	33	-	-	-	36	-	-	-
Match Period																
First Half	8	12.7 (6.4-25.4)	28 (8-47)	351 (176-702)	31	12.8 (9.0-18.2)	23 (15-32)	298 (210-424)	129	20.8 (17.5-24.7)^{5}	29 (23-35)	605 (509-719)^{5}	168	9.1 (7.8-10.6)	28 (23-32)	253 (217-294)
-Q1	1	-	-	-	10	8.3 (4.5-15.4)	30 (9-51)	249 (134-463)	54	17.4 (13.3-22.8)	35 (24-46)	610 (468-797)^{5}	65	3.5 (2.8-4.5)	35 (25-45)	123 (96-157)
-Q2	7	22.2 (10.6-46.7)	22 (6-38)	483 (230-1013)	21	17.4 (11.3-26.7)	21 (12-29)	356 (232-546)	75	24.2 (19.3-30.4)	25 (19-31)	605 (482-758)	103	5.6 (4.6-6.8)	24 (19-29)	132 (109-160)
Second Half	15	23.8 (14.4-39.5)	22 (11-33)	526 (317-872)	61	25.2 (19.6-32.4)^{F}	22 (16-29)	563 (438-724)^{F}	160	25.8 (22.1-30.1)	27 (22-31)	694 (595-811)	236	12.8 (11.2-14.5)	25 (22-29)	325 (286-369)
-Q3	9	28.6 (14.9-55.0)	21 (7-34)	588 (306-1130)	35	29.0 (20.8-40.3)^{1}	25 (15-35)	729 (523-1015)^{12}	90	29.0 (23.6-35.7)^{1}	27 (21-33)	787 (640-968)	134	7.2 (6.1-8.6)	26 (21-31)	190 (160-225)
-Q4	6	19.1 (8.6-42.4)	24 (5-44)	464 (208-1033)	26	21.5 (14.6-31.6)	19 (11-27)	408 (278-599)	70	22.6 (17.9-28.6)	27 (20-33)	601 (475-759)	102	5.5 (4.5-6.7)	24 (19-30)	135 (111-164)
Unknown	3	-	-	-	27	-	-	-	140	-	-	-	170	-	-	-

Note: Injury events are ordered based on the under-18 injury incidence. Incidence, severity and burden are not displayed where n<3. When comparing across age groups, significantly greater than is represented by: 3: U13; 5: U15. When comparing within an age group, significantly greater than is represented by: 1: Q1; A: Accidental Collision; F: First Half; K: Tackling; L: Lineout; M: Maul; N: Running; O: Other; R: Ruck; S: Scrum; T: Trunk; U: Upper Limb.

3.4.10 Concussion

Concussions accounted for 23% of all recorded injuries at U13 (n=6; 4.8 injuries / 1000h, 95% CI=2.1,10.6), which was similar to the proportion seen at U15 (26%; n=31; 6.4 injuries / 1000h, 95% CI=4.5,9.1) and U18 (27%; n=114; 9.2 injuries / 1000h, 95% CI=7.7=11.1). There were no significant differences in concussion incidence between the different age groups, although the burden of concussion injuries was significantly higher ($p=0.03$) at U18 (273 days / 1000h, 95% CI=227,328) compared with U15 (162 days / 1000h, 95% CI=114,230) (table 4.5).

The incidence and burden of concussions caused by tackles at U18 was significantly higher than all other events ($p<0.01$); with the incidence (3.8 injuries / 1000h, 95% CI=2.8,5.0) and burden (115 days / 1000h, 95% CI=86,153) of concussions caused by tackling significantly higher ($p<0.01$) than that of concussions caused whilst being tackled (incidence: 1.5 injuries / 1000h, 95% CI=0.9,2.3; burden: 47 days / 1000h, 95% CI=30,75). There were no differences in the incidence or burden of concussions between playing positions.

Table 4.5: Incidence, severity and burden for concussion event and playing position.

	Under-13				Under-15				Under-18				Overall			
	n	**Incidence, injuries/1000h (95% CI)**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI)**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**
Overall																
Overall	6	4.8 (2.1-10.6)	26 (5-47)	125 (56-278)	31	6.4 (4.5-9.1)	25 (16-35)	162 (114-230)	114	9.2 (7.7-11.1)	30 (24-36)	273 (227-328)^{5}	151	8.2 (7.0-9.6)	29 (24-34)	233 (199-274)
Event																
Tackle	5	4.0 (1.7-9.5)	27 (3-51)	109 (45-261)	18	3.7 (2.3-5.9)^{R}	26 (13-38)	95 (60-151)^{R}	66	5.3 (4.2-6.8) AMORS	30 (22-37)	157 (124-200) AMORS	89	4.8 (3.9-5.9)	29 (22-35)	137 (112-169)
-Tackling	5	4.0 (1.7-9.5)	27 (3-51)	109 (45-261)	10	2.1 (1.1-3.8)	27 (9-45)	56 (30-104)	47	3.8 (2.8-5.0)^{K}	30 (21-40)	115 (86-153)^{K}	62	3.4 (2.6-4.3)	30 (22-37)	99 (77-127)
-Tackled	0	-	-	-	8	1.7 (0.8-3.3)	24 (7-40)	40 (20-79)	19	1.5 (1.0-2.4)	27 (14-41)	42 (27-66)	27	1.5 (1.0-2.1)	26 (15-37)	38 (26-56)
Ruck	0	-	-	-	2	-	-	-	18	1.5 (0.9-2.3)^{MS}	33 (16-49)	47 (30-75)^{MS}	20	1.1 (0.7-1.7)	31 (16-46)	34 (22-52)
A.Collision	1	-	-	-	7	1.4 (0.7-3.0)	24 (3-44)	34 (16-72)	15	1.2 (0.7-2.0)	27 (12-42)	33 (20-54)^{S}	23	1.2 (0.8-1.9)	26 (14-37)	32 (21-48)
Other	0	-	-	-	0	-	-	-	5	0.4 (0.2-1.0)	42 (5-79)	17 (7-41)^{S}	5	0.3 (0.1-0.6)	42 (5-79)	11 (5-27)
Maul	0	-	-	-	0	-	-	-	1	-	-	-	1	-	-	-
Scrum	0	-	-	-	0	-	-	-	1	-	-	-	1	-	-	-
Lineout	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-
Running	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-
Unknown	0	-	-	-	4	-	-	-	8	-	-	-	12	-	-	-
Playing Position																
Forwards	5	8.6 (3.6-20.7)	27 (3-51)	232 (97-558)	16	6.2 (3.8-10.1)	28 (13-42)	173 (106-282)	59	8.9 (6.9-11.5)	31 (22-40)	279 (216-360)	80	4.3 (3.5-5.4)	30 (23-37)	131 (105-163)
Backs	1	-	-	-	13	5.8 (3.3-9.9)	24 (11-38)	141 (82-242)	47	8.1 (6.1-10.8)	29 (20-37)	233 (175-311)	155	8.4 (7.2-9.8)	28 (20-35)	232 (198-271)
Unknown	0	-	-	-	2	-	-	-	8	-	-	-	10	-	-	-

Note: Injury events are ordered based on the under-18 injury incidence. Incidence, severity and burden are not displayed where n<3. When comparing across age groups, significantly greater than is represented by: 5: U15. When comparing within an age group, significantly greater than is represented by: A: Accidental Collision; K: Tackling; M: Maul; O: Other; R: Ruck; S: Scrum.

4.4 Discussion

This three-season study is the first to describe rugby union injuries at three different age groups in an English secondary schoolboy setting. There were three key findings: (1) The incidence and burden of injury was significantly higher at U18 than U13 and U15; (2) the difference in overall incidence and burden is primarily due to injuries in the tackle; (3) concussion was the most common type of injury in all age groups.

4.4.1 Injury Incidence, Severity & Burden

The U18 injury incidence (34.6 injuries / 1000h) in this study was similar to the U18 injury incidence reported by Palmer-Green et al. (2013) (35 injuries / 1000h) and the sub-elite under-19 injury incidence reported by Barden and Stokes (2018) (29 injuries / 1000h); both of which were in an English schoolboy setting. It was also similar to the injury incidence of first fifteen Irish schoolboy players, who were found to have a match injury incidence of 29 injuries / 1000h (Archbold et al., 2017). A key finding of this study is that injury incicence did increase with age, in line with the findings of other studies of youth rugby, including a review of youth rugby injuries (Bleakley et al., 2011) and a more recent study on rugby-related injury insurance claims in New Zealand (Quarrie et al., 2020). It is possible that, as players mature, increases in mass, strength and speed produce greater forces within contact events (McKay et al., 2019). It is also possible that the characteristics of the game are different in older age groups and that they are playing to a higher standard as they get older. Comparisons between different levels within the same age group have shown that a higher level of play has been linked to an increase in injury incidence (Leahy et al., 2019; Barden and Stokes, 2018; Palmer-Green et al., 2013).

Whilst injury incidence and burden increased significantly with age, both mean and median severity were similar in all three age groups. The greater mass, strength and speed of older players (McKay et al., 2019) might be expected to result in more severe injuries, but it is possible that younger players are managed more conservatively, increasing their time loss. In contrast, older players may perceive more pressure and have more of a desire to return to play sooner (Creighton et al., 2010), reducing their time loss. It is also possible that there are differences in the medical resources available to players of different ages. However, the findings of this study suggest that it is the increase in occurrence of injury that is largely responsible for the increased injury burden, rather than an increase in severity.

4.4.2 Injury Event

The tackle was the game event most commonly associated with injury in all age groups, which is consistent with the findings of other studies across all levels of the sport (Bleakley et al., 2011; Fuller et al., 2018; Roberts et al., 2013; England Rugby, 2019; Palmer-Green et al., 2013). Given that the tackle is responsible for the most injuries at all age groups and the injury incidence and burden increases with age, it appears that the tackle is primarily responsible for this. Fuller et al. (2007a) highlighted that in professional rugby most injuries were caused in the tackle because it was the most common event, rather than because it caused the most injuries per event (propensity). Currently, the number of contact events and their propensity to cause injury are unknown within youth rugby. This should be investigated to determine whether the greater tackle injury incidence at U18 is due to an increase in the number of tackles or an increase in the risk that they pose.

What is unusual is that this study found the incidence of U18 tackling injury incidence (10.7 injuries / 1000h) to be significantly lower than that of being tackled (8.0 injuries / 1000h), which is not consistent with the literature. It is possible that there are more tacklers involved in the tackle in English schoolboy rugby than in other settings, thus increasing the number of opportunities that there are for tacklers to get injured. It is also possible that there are deficiencies in their tackling technique, when compared to other levels of the sport. Research into tackles within both professional rugby (Meintjes et al., 2021) and during an U18 tournament (Burger et al., 2016) found that better tackling technique was associated with a non-injury outcome. It has also been found that technical deficiencies were linked with an increase in head contact during a tackle, when investigated within South African and New Zealand men's professional and semi-professional rugby (Davidow et al., 2018). A review of the literature surrounding rugby union tackles concluded that safe tackle technique is effective technique (Den Hollander et al., 2021). Whilst the U18 age group had the highest overall and tackle injury incidence, it is important that good tackling technique is reinforced at all ages.

4.4.3 Injury Region, Site & Type

In line with the findings of Archbold et al. (2017), this study found the knee and shoulder to be areas of concern. The proportion of knee injuries differed quite dramatically for each age group (U13: 23%; U15: 4%; U18: 11%), but shoulder injuries were consistently the second or third most common site of injury at all age groups (U13 15%; U15: 14%; U18: 12%). The findings of this study highlight the importance of the recommendation by Palmer-Green et al. (2013): to identify prevention strategies for shoulder and knee injuries within youth rugby. It does appear, however, that the lower limb is of greater concern than the upper limb at U18, despite there being no significant differences between the injury incidence of these regions at U13 and U15.

Whilst this is the case, the most common injury site and type within all age groups was the head and nerve injury, respectively, which reflects the high incidence of concussion. The U18 concussion incidence (9.2 injuries / 1000h) was greater than previously reported in Irish U18 players (6 injuries / 1000h) (Archbold et al., 2017) and English sub-elite under-19 players (4 injuries / 1000h) (Barden and Stokes, 2018), both of which also used a 24 hour time-loss definition. The rates which were found in these two studies were more similar to that seen in the U13 (4.8 injuries / 1000h) and U15 (6.4 injuries / 1000h) age groups within this study. As these studies were conducted several years ago, it is possible that concussion awareness has improved since, which could explain the difference in concussion incidence. Whilst other injury sites and types are important, reducing the incidence of concussion should be the focus of future interventions.

4.4.4 Injury Prevention

The prevention of sports injuries is of great importance for sporting bodies, across all levels of participation (Finch and Staines, 2018), and several interventions have elicited positive results. In a randomised control trial, England Rugby’s Activate exercise programme reduced concussions by 59% when players completed the programme three or more times per week (Hislop et al., 2017). South Africa’s rugby safety initiative, BokSmart, found success in improving injury prevention behaviours through education of topics such as injury management, contact event technique and physical conditioning (Brown et al., 2015a); although the programme’s effect on injury incidence was not investigated. Given that concussion has been highlighted as a concern and that the tackle is responsible for both the most injuries and concussions, it is recommended that the tackle be the focus of any future interventions. As Archbold et al. (2017) established that using a head guard did not reduce the risk of concussion, something which was also found within English professional rugby (Stokes et al., 2021a), it may be that an intervention which focuses on tackle technique or law change would be most appropriate within an English schoolboy setting. Match events and characteristics of the tackle at different age groups should be investigated, so that population specific recommendations can be made.

4.4.5 Limitations

Many of the schools taking part only had the staff available to include one team within the study. Due to the increased importance placed on U15 and U18 competition, these age groups were normally prioritised for inclusion in the project. Not only were fewer U13 teams included in the study, but these teams played less matches and provided less exposure per match, due to the smaller team size and shorter matches. This resulted in a small sample size for the U13 age group, which may have been underpowered. In some cases, the data was sparse, however the use of a Bonferroni correction reduced the risk of type 1 error.

It is possible that self-selection bias played a role in the findings, as schools with the most rugby-related injuries may have been more motivated to provide data, to address this issue. It is also possible that the schools captured within this study represent those which have the greatest resources, as well-funded schools are more likely to have the staff available to support the collection of data.

As injuries with no, or estimated, time-loss were excluded from the severity and burden calculations, it is possible that these figures are different to those which are stated. It could be argued that severe injuries are more likely to have an unknown or estimated time-loss and that they may account for the majority of unknown injuries; suggesting that severity and burden is higher in reality. However, as only 3% (n=16) of injuries with a known severity were considered severe, but 19% (n=110) of all injuries had an unknown severity, it is likely that this is not the case.

4.5 Conclusion

This study collected 574 match injuries and 18,485 player-hours of exposure from 66 English secondary school teams, over three seasons. The U18 age group had a significantly higher injury incidence and burden than the two younger age groups. The tackle was responsible for the most injuries at all age groups, but it is not possible to tell whether the increase in incidence with age is because there are more tackles per game or because individual tackles are more likely to cause injury. Understanding the number of contact events within the games at each age group would enable researchers to identify which events have the highest propensity for injury. Concussion was the most common type of injury at all age groups, but identifying and addressing issues with the tackle may, in turn, reduce the number of concussions.

CHAPTER FIVE

IDENTIFYING MATCH EVENTS AND CALCULATING THEIR PROPENSITY FOR INJURY WITHIN SCHOOLBOY RUGBY UNION

This study is the first to investigate youth rugby match events and their propensity to cause injury within an English schoolboy setting. Over three seasons (2017/18-2019/20), 574 match injuries and 18,485 player-hours of match exposure were collected from across three age groups: under-13 (U13), under-15 (U15) and under-18 (U18). In addition, video footage from 60 matches was analysed, 20 from each age group, as a representative sample to estimate the quantity of game events which occur at each age group. The game was then described at each age group and the propensity (injuries / 1000 events) and days lost / 1000 events was then calculated for contact events. The tackle was the most common event at all age groups (U13: 212; U15: 187; U18: 230 per match). At all age groups accidental collisions had the highest propensity to cause injury (U13: 25.2 injuries / 1000 events; U15: 39.9 injuries / 1000 events; U18: 24.9 injuries / 1000 events) and were responsible for the most days lost / 1000 events (U13: 437 days / 1000 events; U15: 1065 days / 1000 events; U18: 847 days / 1000 events). Both the number of successful / break / incomplete tackles (U13: 169; U15: 154; U18: 197 per match) and propensity of tackles to cause injury (U13: 1.0 injury / 1000 events; U15: 1.7 injuries / 1000 events; U18: 2.9 injuries / 1000 events) was higher at U18 than at U13 and U15. Re-enforcing proper tackle technique and investigating strategies to reduce the number of tackles is important at all age groups.

5.1 Introduction

The majority of rugby union injuries are caused by contact events (Tucker et al., 2017a; Viviers et al., 2018), with the tackle responsible for approximately 60% of all youth rugby injuries (chapter four) (Palmer-Green et al., 2013; Haseler et al., 2010; Hendricks et al., 2017). Within English schoolboy rugby union, Palmer-Green et al. (2013) found that in under-18 schoolboy matches the tackle had an injury incidence of 21 injuries / 1000h (tackled: 12 injuries / 1000h; tackling: 9 injuries / 1000h), which was similar to the sub-elite under-19 incidence of 19 injuries / 1000h found by Barden and Stokes (2018) (tackled: 12 injuries / 1000h; tackling: 7 injuries / 1000h). However, whilst incidence describes how common an injury is, it does not describe the number of injuries per event (propensity). This information is important so that it can be determined whether an injury is caused by a high quantity of events or by an event that has a high chance of resulting in injury.

Video analysis, which can be used to provide objective and quantifiable data (Van Den Berg and Malan, 2010; Waldron, Worsfold, Twist and Lamb, 2014a), can provide an insight into match events. Much of the available match analysis research in rugby union has focused on games in a professional and international setting, often using time-motion analysis to determine player and position-specific demands (Quarrie et al., 2013; Roberts et al., 2008), rather than focusing on the contact events which cause injury. A review by Till et al. (2020) identified three studies investigating the match demands of English schoolboy rugby, however these all focused on locomotor characteristics and it was concluded that the collision activity of youth rugby union players is yet to be extensively researched. One study of under-18 academy rugby has investigated contact events, finding that forwards were exposed to 26±9 contact events per game (9±5 tackles), compared to 14±6 for backs (6±3 tackles), however only six matches were analysed.

Fuller et al. (2007a) used match analysis to determine the number of contact events within professional men's rugby union matches and to describe the propensity of injury per event, using a 24-hour time-loss injury definition, for the 2003/04 and 2005/06 seasons. They reported 221 tackles (6.1 injuries / 1000 events), 143 rucks (2.0 injuries / 1000 events) and 29 scrums (8.1 injuries / 1000 events) per game, with collisions responsible for the most injuries per 1000 events (10.5 injuries / 1000 events). A similar study in a men's community setting, which collected data from three seasons (2009-12), but used a 7-day time-loss definition for injuries, reported 141 tackles (2.3 injuries / 1000 events), 115 rucks (0.5 injuries / 1000 events) and 32 scrums (0.7 injuries / 1000 events) per game. The illegal collision tackle was found to have the highest propensity for injury (15.0 injuries / 1000 events) (Roberts et al., 2015).

The incidence of injury in youth rugby has been reported (chapter four) (Barden and Stokes, 2018; Palmer-Green et al., 2013), but it is important that the characteristics of matches are investigated so that the number of injuries per event can be calculated and the highest risk (injuries / 1000 events) events identified. There is currently minimal data describing youth rugby gameplay and none in an English schoolboy setting. By understanding the game at each age group and identifying where the greatest risks lie, we will be able to inform population-specific injury prevention strategies, if required. This study will describe the events occurring within English schoolboy rugby union and their propensity to cause injury for the under-13 (U13), under-15 (U15) and under-18 (U18) age groups.

5.2 Methods

5.2.1 Study Design & Setting

This is a cross-sectional descriptive study which describes rugby match events and their propensity for injury within an English secondary school setting. Epidemiological injury data was collected over three seasons (2017/18-2019/20) to calculate the incidence, severity and burden of injury. A representative sample of matches were analysed to estimate the number of contact events within youth rugby matches. These results were then scaled to the epidemiological sample in order to calculate the propensity of injury.

5.2.2 Study Size

In total, 60 matches were analysed for match characteristics, 20 at each of the three age groups: U13, U15 and U18. To ensure that sufficient epidemiological injury data was collected, schools and teams other than those involved in filming were recruited. In total, epidemiological injury data was collected from 1148 matches (66 teams, 35 schools) in order to calculate propensity.

5.2.3 Participants

Both epidemiological data and match footage was collected from schools involved with England Rugby’s Youth Rugby Injury Surveillance Project. A database of school contact details was created and updated each year, with the schools being invited to take part four months before the start of the season. If there was no reply, a second follow-up email was sent two weeks later. There was no limit to the number of teams that could submit data from each school, but only boys’ teams in the U13, U15 and U18 age groups were eligible.

Ethical approval for the study was obtained from the Research Ethics Approval Committee for Health (REACH). Before any data was collected, player (APPENDIX E), parent (APPENDIX F) and staff (APPENDIX G) information sheets, player assent (APPENDIX H) forms and parental (APPENDIX I) and staff (APPENDIX J) consent forms were sent electronically using Online Surveys (Online Surveys, 2021). Opposition (APPENDIX K) and match official (APPENDIX L) consent for filming of matches was gained by the company filming the matches.

5.2.4 Variables

Epidemiological data was collected in accordance with the Consensus Statement on injury definitions and data collection procedures for studies of injury in rugby union (Fuller et al., 2007b). A 24-hour time-loss definition was used, where injuries were recorded if a player was unable to take a full part in training or match play for more than 24 hours from midnight at the end of the day that the injury was sustained. U13 games lasted 50 minutes, U15 games lasted 60 minutes and U18 games lasted 70 minutes. Match exposure was classified as play between teams from different schools and was calculated using the formula:

$$\text{Exposure (Player-Hours)} = \text{Match Length (Minutes)} \times \text{Number of Players (n)} / 60$$

The definitions used for match analysis were based on the consensus on a video analysis framework of descriptors and definitions by the rugby union video analysis consensus group (Hendricks et al., 2020) and England Rugby’s Operational Definitions Manual (England Rugby, 2020b). Where a suitable definition could not be found, an original definition was created. Definitions for key events can be seen in table 5.1.

Table 5.1: Match event definitions.

Event	Definition
Match Descriptors	
Total Match Time	The sum of the time played in the first and second halves; from kick-off until the referee signals the end of the half. For youth games the time should not be stopped.
Ball In Play Time	The amount of time the ball is in the possession of any of the players or is in a position where either team can contest the ball. Time when play has been stopped by the referee is considered out of play and does not contribute to ball in play time.
Contact Events	
Accidental Collision	Where contact is made unintentionally; normally where one or more players are not aware of the situation.
Lineout	A lineout is formed on the mark of touch. Each team forms a single line parallel to and half a metre from the mark of touch on their side of the lineout between the 5 m and 15 m lines. A minimum of two players from each team are required to form a lineout.
- Quick	A quick line-out (quick thro w) can take place before a line-out is formed and is observed when a player whose feet are both outside the field of play throws the ball parallel to or towards the thrower's own goal line, between the mark of touch and the thrower's own goal line, so that it reaches the 5 m line before it touches the ground or makes contact with a player.
Maul	A maul begins when a player carrying the ball is held by one or more opponents, and one or more of the ball carrier's teammates bind on the ball carrier. A maul therefore consists, when it begins, of at least three players, all on their feet; the ball carrier and one player from each team.
Ruck	A ruck is formed when at least one player from each team is in contact, on their feet and over the ball, which is on the ground. Once a ruck is formed, additional players joining the ruck to compete for the ball, without being guilty of foul play, are considered rucking.
Scrum	A scrum is formed in the field of play when eight players from each team, bound together in three rows for each team, engage with their opponents so that the heads of the front rows are interlocked. Scrum engagement occurs when the front-row of each team make contact with each other.
- Scrum Time	The time (in minutes: seconds) from the engagement to when the ball is played or the whistle is blown to reset the scrum.
Tackle	A tackle is any event where 1 or more tacklers (player or players making the tackle) attempted to stop or impede the ball carrier (player carrying the ball) whether or not the ball carrier was brought to ground.
- Successful	When a tackle break does not occur, and either player goes to ground or the ball carrier is held up and cannot progress further, whether they offload the ball or not.
- Break	The ball carrier successfully penetrates the attempted tackle and continues to advance.
- Incomplete	The tackler makes contact, but actively decides not to complete the tackle. This is common after the ball is offloaded.
- Unsuccessful (Missed)	There is no meaningful contact and the tackler fails to tackle the ball carrier, thus allowing the ball carrier to advance during open play.
Match Events	
Clean Break	The number of times a ball carrier moved through a straight line between two defenders, or a defender and the touch line, without being physically contacted by the defender.
Kick*	Any kick that is executed within open play.
Pass	The ball is received from a teammate's pass / offload or intercepted from the opposition's pass.
- Offload	A player has taken the ball into contact and is able to move the ball to a teammate before hitting the ground.
Other Events	
Try	A player successfully grounds the ball over the opposition try line.
Foul	Total number of foul plays during the match.

*Kicks include tap & go and drop goal kicks, but exclude kick-offs, conversions and penalty kicks.

5.2.5 Data Collection

Epidemiological data was collected over three seasons, from September 2017 to April 2020. A nominated project co-ordinator, normally a coach or physiotherapist, was sent a spreadsheet (APPENDIX B) to use for data collection. This was used to capture epidemiological data (match exposure and match injuries). If requested, a paper alternative was available (APPENDICES C & D). Project co-ordinators were asked to return data at the end of each season by uploading their spreadsheet onto a secure University server, using a link sent to them, or by posting their paper forms to the research team.

Match footage was collected over the first two seasons, from September 2017 to April 2019. To ensure that footage was "typical" of the game being played, no play-off games or finals matches were filmed. Camera operators were instructed to follow the ball, but to zoom in to contact events where possible, and to film from as high as possible at the side of the pitch. Footage for the U13 age group was collected during the 2017/18 season (n=49) and footage for the U15 (n=31) and U18 (n=58) age groups during the 2018/19 season. Whilst this meant that match footage was taken from a single season, rather than three seasons for the epidemiological data, no rule changes occurred during this time and there was no evidence that the injury rates had changed. Matches which were incomplete or where the footage was unclear were excluded from the sample (U13: 4/49); U15: 5/31; U18: 8/58), then 60 matches were chosen at random for analysis, 20 from each age group.

5.2.6 Match Analysis

All analysis was carried out on Nacsport Pro Plus Match Analysis Software (chapter three) (Nacsport, 2021). A coding window was designed (figure 3.1), using "categories" for key events and "descriptors" to add further detail (table 5.1). The software allowed the coder to pause, rewind and watch the footage in slow motion.

5.2.6.1 Pre-Coding Validation

One coder analysed all of the matches. To ensure that the coder was analysing matches correctly, they analysed a single match which had previously been analysed by an expert coder (> 10 years of experience). The coder was required to be within 10% of the expert coder for all key events, before being allowed to collect data. This was done to ensure that they were at a standard set by an expert, before analysing matches used within this study. However, the emphasis was placed on the post-coding validation. The focus for this was on validity and repeatability, due to the fact that there was a single coder.

5.2.6.2 Post-Coding Validation

Once the data collection had been completed, the match coding was validated by the same expert coder, who re-coded one match from each age group. The total count for key events was compared to the coder's analysis. The percentage that the coder was away from the expert coder was then calculated, for both the number of events and time; alongside means for each event, age group and overall. When the number of contact or game events was less than 10 for both coders this was excluded from the validation, being removed from the mean calculations. This was done as anything other than complete agreement would have resulted in a disagreement of over 10%, due to the small sample size. Where the agreement was not within 10%, a decision was made on a case-by-case basis. This was only the case for penalties, as it was difficult to distinguish between free kicks and penalties due to the quality of the footage. For this reason, these were combined and are referred to as "fouls". Overall, the coder was 2.5% from the expert coder.

5.2.6.3 Intra-Rater Reliability

Intra-rater reliability was also assessed, with the coder re-analysing half of a game from each age group (>1 month from original analysis). The same method was used to validate their coding, using the percentage that they were away from their original analysis. Overall, the coder was within 0.9% of their original analysis.

5.2.7 Statistical Analysis

Injury incidence was defined as the number of injuries per 1000 player-hours (injuries / 1000h). Injury severity was defined as the number of full days that elapsed from the date of injury until the date of the player's return to full participation in team training and availability for match selection. Burden was calculated by multiplying the mean severity by injury incidence, giving days lost per 1000 player-hours (days lost / 1000h). Propensity was defined as the number of injuries per 1000 events; days lost / 1000 events was also calculated.

Epidemiological data received from schools was entered into a master spreadsheet. Any injuries which did not have corresponding match exposure or were not 24-hour time-loss injuries were excluded. Injuries with no return to play date or which had time-loss estimated were included when calculating incidence but excluded for the severity and burden calculations. Data from the match analysis was exported from Nacsport, checked for completeness and input into a master spreadsheet. If an injury was identified during the match analysis which had not been recorded by a participating school, this was followed up with the project coordinator to ensure that it was not a time-loss injury.

Analysis was conducted in Microsoft Excel (95% Poisson Confidence Interval, Z score, t-test) and on IBM SPSS Statistics 25 (ANOVA, Shapiro-Wilk test). Match events were summarised as mean events per game, with a Standard Deviation (SD), and mean events per hour of gameplay. To identify how often tackles were unsuccessful at each age group and to enable comparison of tackles with the most significant contact, total tackles were broken down into unsuccessful (missed) tackles and successful / break / incomplete tackles. An ANOVA, which is robust to both normal and non-normal data (Maxwell, 1990), with a post-hoc Tukey test was conducted to determine whether there were differences in the number of (selected) events in each game, across age groups (U13 v U15; U13 v U18; U15 v U18). A Bonferroni correction (Bonferroni, 1936) was used to reduce the chance of Type 1 error. Where data was missing for one age group and only one comparison was required, which was the case for lineouts, the data was checked for normality using a Shapiro-Wilk test and a t-test was used.

Injury incidence and burden were calculated with 95% Poisson Confidence Intervals and were used to calculate both propensity and the number of days lost / 1000 events. This was done by calculating the number of events / 1000h, based on the data collected during the match analysis. This was then combined with the incidence (number of injuries / 1000h) to calculate the number of injuries / 1000 events (propensity). The same process was used to determine days lost / 1000 events, using burden (days lost / 1000h).

The log of the rate ratio was used to calculate Z scores, with the assumption of normality of the data. These were used to compare propensity and days lost / 1000 events, both within and across age groups. This was done for accidental collisions, lineouts, mauls, rucks, scrums and total tackles. A Holm-Bonferroni (Holm, 1979; Wright, 1992) correction was used to minimise the risk of Type 2 error. Results where $p<0.05$ were considered significant.

5.3 Results

5.3.1 Injuries

Overall, 574 injuries and 18,485 player-hours of match exposure were collected. The injury incidence was 20.7 injuries / 1000h (95% CI=14.1,30.3) at U13, 24.6 injuries / 1000h (95% CI=20.6,29.5) at U15 and 34.6 injuries / 1000h (95% CI=31.5,38.1) at U18. The injury burden was 477 days / 1000h (95% CI=325,701) at U13, 602 days / 1000h (95% CI=503,721) at U15 and 941 days / 1000h (95% CI=856,1035) at U18 (table 5.2).

Table 5.2: An overview of the epidemiological data collected.

	Under-13	**Under-15**	**Under-18**	**Overall**
Injuries, n	26	119	429	574
Exposure, player match-hours	1259	4834	12393	18485
Incidence, injuries/1000h (95% CI)	20.7 (14.1-30.3)	24.6 (20.6-29.5)	34.6 (31.5-38.1)[35]	31.1 (28.6-33.7)
Severity, mean days (95% CI)	23 (14-32)	25 (20-29)	27 (24-30)	26 (24-29)
Burden, days/1000h (95% CI)	477 (325-701)	602 (503-721)	941 (856-1035)[35]	820 (755-890)

5.3.2 Matches

The ball was in play for 55% of the match at U13 (27:33), compared to 43% (26:33) at U15 and 44% (32:12) at U18 (minutes: seconds) (table 5.3). On average, U13 matches lasted for exactly the correct amount of time (50:00), but 60% (n=12) of matches did go over the allocated time limit. 80% of U15 (n=16) and 85% of U18 (n=17) matches also went over the allocated time limit, but only by an average of 01:57 and 02:46 (mins) for U15 and U18, respectively. A small number of matches ran over the allocated time limit by >10% (U13, n=1; U15: n=3; U18: n=3).

Table 5.3: An overview of the match analysis data collected.

	Under-13	**Under-15**	**Under-18**	**Overall**
Matches Analysed, n	20	20	20	60
Mean Match Time, mm:ss (SD)	50:00 (04:17)	61:57 (04:59)	72:46 (03:41)	61:35 (10:21)
Mean Ball In Play Time, mm:ss (SD)	27:33 (03:52)	26:33 (02:31)	32:12 (03:49)	28:46 (4:16)

5.3.3 Match Characteristics & Contact Events

There were 430 (±61) contact events (accidental collisions, lineouts, mauls, rucks, scrums, tackles) per match at U18, compared with 338 (±67) at U13 and 328 (±44) at U15. There were no significant differences in the number of any of the contact events between U13 and U15. The tackle was the most common contact event at all age groups, with 212 (±44) per match at U13, 187 (±29) per match at U15 and 230 (±40) per match at U18. There were significantly more tackles at U18 than at U15 ($p<0.01$). The U18 age group had significantly more successful / break / incomplete tackles (197±37) than both the U13 (169±37, $p=0.04$) and U15 (155±27, $p<0.01$) age groups. The proportion of unsuccessful (missed) tackles was 11% at U18 (11%), compared 15% at U13 and 16% at U15. There were significantly more accidental collisions at U18 (4±3) than U13 (2±2, $p=0.03$) and more rucks at U18 (143±29) than at both U13 (96±27, $p<0.01$) and U15 (93±18, $p<0.01$) (table 5.4).

The average scrum duration was the same for all age groups (0:04±00:01 secs) and there were no significant differences in the number of scrums across all age groups. U18 matches had more lineouts per match (18±3.7) than U15 teams (14±4, $p<0.01$), but a higher proportion of lineouts were won by the team throwing in at U15 (87%) than U18 (78%). The number of clean breaks was higher at U13 (14±6) than both of the older age groups (U15: 10±4, $p=0.03$; U18: 8±4, $p<0.01$). U13 players passed significantly more per match (219±53) than U15 teams (175±31, $p<0.01$), with a greater proportion of offloads at U13 (20%) than at U15 (17%) and U18 (13%). There were significantly more kicks during U18 matches (44±12) when compared with U13 (31±14, $p<0.01$) and U15 (30±8, $p<0.01$).

5.3.4 Scoring & Fouls

Fewer tries were scored each match at U18 (6±2) than both of the younger age groups (U13: 10±3, $p<0.01$; U15: 8±3, $p=0.03$), but there were no significant differences in the number of points scored per match. There were 33 fouls per match at U13, compared to 31 at U15 and 37 at U18. Three cards were given to players across all matches; none of which were red cards (table 5.4).

Table 5.4: Contact events, match events and scoring.

	Under-13			Under-15			Under-18			Overall		
	Total Events, n (%)	Mean / Game, n (SD)	Mean / Hour, n	Total Events, n (%)	Mean / Game, n (SD)	Mean / Hour, n	Total Events, n (%)	Mean / Game, n (SD)	Mean / Hour, n	Total Events, n (%)	Mean / Game, n (SD)	Mean / Hour, n
Contact Events												
A.Collision	41	2.1 (2.0)	2.5	56	2.8 (1.5)	2.7	77	3.9 (2.5)[3]	3.2	174	2.9 (2.2)	2.8
Lineout*	0	-	-	270	13.5 (3.6)	13.1	356	17.8 (3.7)[5]	14.7	626	15.7 (4.2)	13.9
- Quick*	0	-	-	21 (8)	1.1 (3.1)	1.0	11 (3)	0.6 (0.7)	0.5	32 (5)	0.8 (2.2)	0.7
- Won*	0	-	-	234 (87)	11.7 (4.3)	11.3	276 (78)	13.8 (3.8)	11.4	510 (82)	12.8 (4.2)	11.4
- Lost*	0	-	-	15 (5)	0.8 (0.9)	0.7	68 (19)	3.4 (1.6)	2.8	83 (13)	2.1 (1.9)	1.8
- Unknown*	0	-	-	0	-	-	1 (0)	0.1 (0.2)	0	1 (0)	0	0
Maul	183	9.2 (5.9)	11.0	234	11.7 (5.6)	11.3	239	12.0 (4.6)	9.9	656	10.9 (5.5)	10.7
Ruck	1924	96.2 (26.9)	115.4	1855	92.8 (17.7)	89.8	2859	143.0 (28.7)[35]	117.9	6638	110.6 (33.8)	107.8
Scrum	390	19.5 (6.6)	23.4	402	20.1 (4.9)	19.5	468	23.4 (5.9)	19.3	1260	21.0 (6.1)	20.5
- Won	259 (66)	13.0 (4.2)	15.5	300 (75)	15.0 (3.3)	14.5	356 (76)	17.8 (4.3)	14.7	915 (73)	15.3 (4.4)	14.9
- Lost	41 (11)	2.1 (1.8)	2.5	25 (6)	1.3 (1.3)	1.2	20 (4)	1.0 (0.9)	0.8	86 (7)	1.4 (1.4)	1.4
- Collapse	12 (3)	0.6 (0.8)	0.7	9 (2)	0.5 (0.7)	0.4	21 (5)	1.1 (1.2)	0.9	42 (3)	0.7 (1.0)	0.7
- Reset	76 (19)	3.8 (3.2)	4.6	68 (17)	3.4 (2.1)	3.3	71 (15)	3.6 (2.8)	2.9	215 (17)	3.6 (2.7)	3.5
- Unknown	2 (1)	0.1 (0.3)	0.1	0	-	-	0	-	-	2 (0)	0 (0.2)	0
- Time, mm:ss	26:45 (3)	1:20 (0:28)	1:36	28:11 (2)	1:25 (0:24)	01:22	34:57 (2)	1:45 (0:38)	01:26	89:53 (2)	1:30 (0:32)	01:28
Tackle	4230	211.5 (43.8)	253.8	3745	187.3 (28.8)	181.3	4591	229.6 (40.0)[5]	189.3	12566	209.4 (41.8)	204.0
- Successful / Break / Incomplete	3387 (80)	169.4 (37.3)	203.2	3093 (83)	154.7 (26.6)	149.8	3947 (86)	197.4 (37.3)[35]	162.7	10427 (83)	173.8 (38.4)	169.3
- Unsuccessful (Missed)	685 (16)	34.3 (11.3)	41.1	582 (15)	29.1 (9.4)	28.2	491 (11)	24.6 (9.2)	20.2	1758 (14)	29.3 (10.8)	28.5
- Unknown	158 (4)	7.9 (5.1)	9.5	70 (2)	3.5 (2.6)	3.4	153 (3)	7.7 (5.4)	6.3	381 (3)	6.4 (5.0)	6.2
Match Events												
Clean Break	284	14.2 (5.5)[58]	17.0	208	10.4 (4.1)	10.1	156	7.8 (3.5)	6.4	648	10.8 (5.2)	10.5
Kick	627	31.4 (13.9)	37.6	608	30.4 (8.3)	29.4	888	44.4 (12.3)[35]	36.6	2123	35.4 (13.4)	34.5
- To Field	225 (36)	11.3 (8.4)	13.5	261 (43)	13.1 (6.3)	12.6	371 (42)	18.6 (8.6)	15.3	857 (40)	14.3 (8.4)	13.9
- To Hand	42 (7)	2.1 (2.2)	2.5	65 (11)	3.3 (1.8)	3.1	152 (17)	7.6 (3.9)	6.3	259 (12)	4.3 (3.6)	4.2
- To Touch	22 (4)	1.1 (1.0)	1.3	180 (30)	9.0 (2.6)	8.7	252 (28)	12.6 (3.6)	10.4	454 (21)	7.6 (5.5)	7.4
- Tap & Go	335 (53)	16.8 (6.4)	20.1	99 (16)	5.0 (3.1)	4.8	112 (13)	5.6 (4.3)	4.6	546 (26)	9.1 (7.2)	8.9
- At Goal*	0	-	-	2 (0)	0.1 (0.4)	0.1	1 (0)	0.1 (0.2)	0	3 (0)	0.1 (0.3)	0.1
- Unknown	3 (0)	0.2 (0.5)	0.2	1 (0)	0.1 (0.2)	-	0	-	-	4 (0)	0.1 (0.3)	0.1
Pass	4371	218.6 (52.6)[5]	262.3	3501	175.1 (30.9)	169.5	4122	206.1 (41.5)	169.9	11994	199.9 (46.4)	194.8
- Offload	864 (20)	43.2 (13.9)	51.8	585 (17)	29.3 (10.4)	28.3	537 (13)	26.9 (8.2)	22.1	1986 917)	33.1 (13.2)	32.2
Scoring												
Points	990	49.5 (16.8)	59.4	1035	51.8 (16.6)	50.1	794	39.7 (12.1)	32.7	2819	47.0 (16.2)	45.8
Try	198	9.9 (3.4)[8]	11.9	165	8.3 (2.6)[8]	8.0	116	5.8 (2.1)	4.8	479	8.0 (3.2)	7.8
Conversion*	0	-	-	99	5.0 (2.4)	4.8	68	3.4 (2.0)	2.8	167	4.2 (2.3)	3.7
Drop Goal*	0	-	-	1	0.1 (0.2)	0	1	0.1 (0.2)	0	2	0.1 (0.2)	0
Penalty Kick*	0	-	-	3	0.2 (0.5)	0.1	25	1.3 (1.4)	1.0	28	0.7 (1.2)	.6
Fouls												
Fouls	650	32.5 (7.8)	39.0	614	30.7 (7.3)	29.7	738	36.9 (5.0)	30.4	2002	33.4 (7.3)	32.5
Cards	1	0.1 (0.2)	0.1	0	-	-	2	0.1 (0.3)	0.1	3	0.1 (0.2)	0

Note: Data displayed is per match. Bold events were compared across age groups. Significantly greater than is represented by: 3: U13; 5: U15; 8: U18.

*The overall figures for events which are not permitted at U13 (lineouts and kicks at goal) only include the U15 and U18 age groups.

5.3.5 Propensity for Injury: Contact Events

Accidental collisions had the highest propensity for injury across all age groups (U13: 25.2 injuries / 1000 events, 95% CI=8.1,78.1; U15: 39.9 injuries / 1000 events, 95% CI=25.1-63.3; U18: 24.9 injuries / 1000 events, 95% CI=17.8,34.9). Tackles had a significantly higher propensity for injury at U18 (2.9 injuries / 1000 events, 95% CI=2.5,3.2) than at U13 (1.0 injury / 1000 events, 95% CI=0.6,1.7, $p<0.01$) and U15 (1.7 injuries / 1000 events, 95% CI=1.3,2.2, $p<0.01$). The tackle had a significantly higher propensity than the lineout (0.3 injuries / 1000 events, 95% CI=0.1,1.3, $p=0.02$), scrum (0.7 injuries / 1000 events, 95% CI=0.3,1.6, $p<0.01$) and ruck (0.9 injuries / 1000 events, 95% CI=0.7,1.2, $p<0.01$) at U18, but did not have a significantly higher propensity than any other event at U13 and U15 (table 5.5).

5.3.6 Days Lost Due to Injury: Contact Events

Accidental collisions were also responsible for the most days lost / 1000 events across all age groups (U13: 437 days / 1000 events, 95% CI=141,1354; U15: 1065 days / 1000 events, 95% CI=671,1690; U18: 847 days / 1000 events, 95% CI=605,1186). Tackles were responsible for the second most days lost per 1000 events at all age groups. U18 tackles (97 days / 1000 events, 95% CI=85,111) resulted in more days lost / 1000 events than both U13 (30 days / 1000 events, 95% CI=17,53, $p<0.01$) and U15 (56 days / 1000 events, 95% CI=43,74, $p<0.01$) tackles (table 5.6).

Table 5.5: The propensity for injury for contact events.

	Under-13			Under-15			Under-18			Overall		
	n	**Incidence, injuries/1000h (95% CI)**	**Propensity, injuries/1000 events (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI)**	**Propensity, injuries/1000 events (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI)**	**Propensity, injuries/1000 events (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI)**	**Propensity, injuries/1000 events (95% CI)**
A. Collision	3	2.4 (0.8-7.4)	25.2 (8.1-78.1)^{RST}	18	3.7 (2.3-5.9)	39.9 (25.1-63.3)^{MRST}	34	2.7 (2.0-3.8)	24.9 (17.8-34.9)^{LMRST}	55	3.0 (2.3-3.9)	29.6 (22.8-38.6)
Tackle	12	9.5 (5.4-16.8)	1.0 (0.6-1.7)	51	10.6 (8.0-13.9)	1.7 (1.3-2.2)	232	18.7 (16.5-21.3)	2.9 (2.5-3.2)^{35LSR}	295	16.0 (14.2-17.9)	2.2 (2.0-2.5)
Maul	1	-	-	1	-	-	5	0.4 (0.2-1.0)	1.2 (0.5-2.8)	7	0.4 (0.2-0.8)	1.0 (0.5-2.1)
Ruck	3	2.4 (0.8-7.4)	0.5 (0.2-1.7)	19	3.9 (2.5-6.2)	1.3 (0.8-2.0)	45	3.6 (2.7-4.9)	0.9 (0.7-1.2)	67	3.6 (2.9-4.6)	0.9 (0.7-1.2)
Scrum	1	-	-	4	0.8 (0.3-2.2)	1.2 (0.5-3.3)	6	0.5 (0.2-1.1)	0.7 (0.3-1.6)	11	0.6 (0.3-1.1)	0.8 (0.5-1.5)
Lineout	0	-	-	0	-	-	2	-	-	2	-	-

Note: Contact events are ordered based on the under-18 propensity. Incidence and propensity are not displayed where n<3. When comparing an event across age groups, significantly greater than is represented by: 3: U13; 5: U15. When comparing a characteristic within an age group, significantly greater than is represented by: L: Lineout; M: Maul; R: Ruck; S: Scrum; T: Tackle.

Table 5.6: The days lost / 1000 events for contact events.

	Under-13			Under-15			Under-18			Overall		
	n	**Burden, days/1000h (95% CI)**	**Days Lost, days/1000 events (95% CI)**	**n**	**Burden, days/1000h (95% CI)**	**Days Lost, days/1000 events (95% CI)**	**n**	**Burden, days/1000h (95% CI)**	**Days Lost, days/1000 events (95% CI)**	**n**	**Burden, days/1000h (95% CI)**	**Days Lost, days/1000 events (95% CI)**
A. Collision	3	41 (13-128)	437 (141-1354)^{MRST}	18	99 (63-158)	1065 (671-1690)^{MRST}	34	93 (67-130)	847 (605-1186)^{LMRST}	55	74 (57-96)	734 (564-956)
Tackle	12	294 (167-518)	30 (17-53)^{MS}	51	352 (267-463)	56 (43-74)^{MS}	232	637 (560-725)	97 (85-111)^{35RS}	295	466 (415-522)	64 (57-72)
Maul	1	-	-	1	-	-	5	15 (6-36)	44 (18-105)^{5}	7	6 (3-13)	16 (8-34)
Ruck	3	37 (12-113)	8 (3-26)	19	101 (64-158)	33 (21-51)^{M}	45	129 (96-172)	32 (24-42)	67	94 (74-119)	24 (19-31)
Scrum	1	-	-	4	7 (3-20)	11 (4-29)	6	7 (3-16)	11 (5-24)	11	4 (2-8)	6 (3-11)
Lineout	0	-	-	0	-	-	2	-	-	2	-	-

Note: : Contact events are ordered based on the under-18 days lost / 1000 events. Burden and days lost / 1000 events are not displayed where n<3. When comparing across age groups, significantly greater than is represented by: 3: U13; 5: U15. When comparing within an age group, significantly greater than is represented by: L: Lineout; M: Maul; R: Ruck; S: Scrum; T: Tackle.

5.4 Discussion

This study is the first to investigate youth rugby match events and their propensity to cause injury within an English schoolboy setting. The key findings were: (1) The tackle is the most common contact event at all age groups; (2) accidental collisions had both the highest propensity for injury and were responsible for the most days lost / 1000 events within all age groups; (3) the U18 tackle had both a higher propensity for injury and was responsible for more days lost / 1000 events than the U13 and U15 age groups.

5.4.1 Tackle Frequency & Propensity

The most common contact event at all age groups was the tackle. The number of tackles per match at U15 was lower than at U13 and U18, despite the shorter game length at U13. This may be due to the smaller pitch size at U13 (U13: maximum 90x60 metres; U15: maximum 100x70 metres) combined with the fact that the ball in play time was similar for both the U13 (27:33) and U15 (26:33) (minutes: seconds) age groups. When compared to the professional game (2003/04 and 2005/06 seasons) (Fuller et al., 2007a), the U18 age group had a similar number of tackles (U18: 230; professional: 221) and rucks (U18: 143; professional: 143). However, despite a shorter game length, there were more than in the men’s community game (tackles: 141; rucks; 115) (2009-12 seasons) (Roberts et al., 2015). Based on the quantity of contact events, the U18 game appears to be more similar to the professional game than the men’s community game, but it should be noted that the cited studies may not be representative of the game being played today.

For tackles, both the propensity for injury and days lost / 1000 events was higher at U18 (propensity: 2.9 injuries / 1000 events; days lost: 97 days / 1000 events) than at U13 (propensity: 1.0 injury / 1000 events; days lost: 30 days / 1000 events) and U15 (propensity: 1.7 injuries / 1000 events; days lost: 56 days / 1000 events). This might be partially because the number of tackles which are successful, breaks or incomplete are greatest at U18 (U13: 169; U15: 155; U18: 197 per match). Whilst there may be some contact during unsuccessful (missed) tackles, there is always contact during tackles with these outcomes. This may mean that more contact is being made at U18. This study found both propensity and days lost / 1000 events to be lower than in a professional setting (propensity: 6.1 injuries / 1000 events; days lost: 127 days / 1000 events) (Fuller et al., 2007a), suggesting that the number of injuries and days lost / 1000 events also appears to increase with playing level, as is the case for injury incidence (Palmer-Green et al., 2013; Leahy et al., 2019; Viviers et al., 2018; Williams et al., 2013). Comparisons were not made to the men's community game, as a 7-day time loss injury definition was used to calculate propensity (Roberts et al., 2015). The tackle is responsible for the most injuries (U13: 9.5 injuries / 1000h; U15: 10.6 injuries / 1000h; U18: 18.7 injuries / 1000h). This is because it is both the event with the second highest propensity for injury and the most common event. For this reason, it should be the focus of injury prevention strategies at all age groups.

One solution to concerns about the tackle is to remove it from the game in certain age groups. A study by Emery et al. (2021) investigated a policy change disallowing body checking in Canadian youth ice hockey; comparing the injury incidence of teams where body checking was and was not permitted. The study found that this law change resulted in both lower rates of injury and concussion. There have been calls to ban the tackle within younger age groups (Pollock, White and Kirkwood, 2017), as it is believed that this would have a similar effect, reducing the incidence of tackle-related injuries. Whilst this is the case, it is important that rugby players are given the opportunity to learn good tackle technique; something which has been linked to both a reduced risk of injury and a reduced risk of head contact (Burger et al., 2016; Davidow et al., 2018). For this reason, it may not be beneficial to stop young players from tackling. Instead, at all age groups, it is important that time is spent teaching proper tackle technique and that methods to reduce the number of tackles in matches investigated. At U13, increasing the pitch size (and thus width) would reduce the density of players and may decrease the number of tackles. Reducing U13 ball in play time (55%), which is higher than at U15 (43%) and U18 (44%), may also reduce the number of tackles and could be achieved by introducing lineouts and kicking at goal. As the clock is not permitted to stop in youth games, this would mean that more time would be spent conducting events which take time to prepare for and carry a lower risk of injury. Future studies should seek to identify ways in which the number of tackles can be reduced across age-grade rugby.

5.4.2 Accidental Collision Frequency & Propensity

Accidental collisions were responsible for the most injuries / 1000 events (U13: 25.2 injuries / 1000 events; U15: 39.9 injuries / 1000 events; U18: 24.9 injuries / 1000 events) and most days lost / 1000 events (U13: 437 days / 1000 events; U15: 1065 days / 1000 events; U18: 847 days / 1000 events) at all age groups. Both Fuller et al. (2007a) (collisions: 10.7 injuries / 1000 events) and Roberts et al. (2015) (illegal collision tackles: 15.0 injuries / 1000 events) found similar findings, although direct comparisons cannot be drawn due to the differences in definitions. It is important that players are educated on the risks of accidental collisions and that coaching focuses on the development of situational awareness as, whilst these events occur infrequently and the incidence of injury is relatively low (U13: 2.4 injuries / 1000h; U15: 3.7 injuries / 1000h; U18: 2.7 injuries / 1000h), the risk of injury per event is high.

5.4.3 Adhering to Law

A study into South African youth rugby found that only 59% of illegal tackles were sanctioned (Brown et al., 2018). Non-sanctioning of illegal events is something which is likely happening within the English schoolboy population. In this study, the referee could not be heard on video and the quality of the footage meant that referee hand signals could not always be seen clearly. Therefore, free kicks and penalties were groups into “fouls”. There were 2,002 fouls recorded across all age groups, yet only three yellow cards, and no red cards, were given to players. Whilst this study did not investigate which of these fouls were awarded for dangerous play, rather than technical infringements, or should have resulted in a card, it is likely that referees are trying to maximise game time, and thus player development, by not awarding cards. Whilst this approach makes sense, it is important that players are reprimanded for illegal or dangerous play and that the laws are reinforced, as reducing the amount of dangerous play may reduce the incidence of injury. What is particularly important is that these lessons are learnt before they start playing at U18, where tackles are both more frequent and pose a higher risk to players.

As both red and yellow cards are rarely being used, it may be beneficial to give referees other tools to use, which is something that has been trialled in other settings. A “replacement red card” rule is being utilised in Australia and New Zealand, which allows a different player to continue playing 20 minutes after the original player had been sent off (Super Rugby, 2021). Given that no red cards were given to players in the present study, something similar to the “green card” used in hockey could be considered (The International Hockey Federation, 2019); this acts as an official warning for a minor offence and results in a two-minute suspension from play. If this was implemented in rugby, it could be used when a referee feels that a player needs to be reprimanded for dangerous play, but that a yellow card is not warranted (i.e., for a penalty offence related to dangerous play). However, from the data collected in this study, it is not possible to tell how many green cards are likely to be awarded in a match.

A small proportion of matches ran over the allocated time limit by over 10% (U13: 5%; U15: 15%; U18: 15%); referees should ensure that matches finish on time to avoid increasing the player's exposure. What these findings do suggest, however, is that generally the exposure used to calculate injury incidence is appropriate, especially at U13. In reality, the injury incidence for the U15 (24.6 injuries / 1000h) and U18 (34.6 injuries / 1000h) teams may be slightly lower (U15: 23.8 injuries / 1000h; U18: 33.3 injuries / 1000h) as the actual mean match time recorded in this study was greater than the standardised match time used to calculate team exposure and, thus, incidence.

5.4.4 Limitations

It is possible that the schools which compete at the highest levels are more likely to be well funded and have the staff available to support the collection of data. Therefore, the findings of this study may represent more skilled rugby squads, or those with a more competitive programme, than the average English schoolboy team.

As the injury epidemiological data was collected over three seasons (2017/18-2019/20), but the match footage was collected over a single season (U13: 2017/18; U15 / U18: 2018/19), it is possible that the footage may not have been representative of all seasons. However, no significant season-to-season variations were seen in injury rates and there were no changes in laws during this period. As the U13 footage was filmed by a different company to the U15 and U18 teams, it is also possible that the quality of the footage was different for this age group, which could have affected the analysis. Whilst this is the case, the proportion of unknown tackle types was similar at all age groups (U13: 4%; U15: 2%; U18: 3%), suggesting that this is not the case. The same message can also be taken from both the intra-rater reliability (U13: 1.1%; U15: 1.0%; U18: 0.8%) and expert validation (U13: 2.1%; U15: 0.5%; U18: 4.7%). As the quality of the footage varied depending on the skill of the camera operator, equipment available and weather, a second camera angle would have been beneficial, as it was not always possible to see each event in detail.

It is also worth noting that the accidental collision was excluded from the validation, due to the small sample size; despite it being highlighted as the highest risk event. Although this could raise concerns, the same number of events were identified during the intra-rater reliability (1st analysis: n=1; 2nd analysis: n=1) and the expert validation only differed by a single event (coder: n=5; expert: n=6). Even if the number of events was increased by 20%, in line with what the expert had found, the re-calculated propensity (U13: 21.0 injuries / 1000 events; U15: 33.2 injuries / 1000 events; U18: 20.8 injuries / 1000 events) and days lost / events (U13: 364 days / 1000 events; U15: 887 days / 1000 events; U18: 706 days / 1000 events) would still be significantly greater ($p<0.01$) than the tackle, which had the second greatest propensity and days lost / 1000 events at all age groups.

5.5 Conclusion

This study is the first to investigate youth rugby match events and their propensity to cause injury within an English schoolboy setting. Accidental collisions had the highest propensity for injury and tackles were the most common event at all age groups. At U18, tackles were both more common and had a higher propensity for injury than at U13 and U15. Non-sanctioning of illegal events is something which is likely happening within the English schoolboy population, so the introduction of a “green card” should be considered, allowing referees to give official warnings and to teach important lessons to young players before the risk if injury increases. Tackle technique should be reinforced and strategies to reduce the number of tackles investigated at all age groups.

CHAPTER SIX

CHARACTERISTICS OF SCHOOLBOY RUGBY UNION TACKLES AND THEIR ASSOCIATION WITH HEAD CONTACT

Within English schoolboy rugby, the tackle is responsible for the majority of injuries and concussions. This study describes the characteristics of the tackle within the under-13 (U13), under-15 (U15) and under-18 (U18) age groups and their association with head contact. 8017 tackles (6774 primary, 1243 adjust) were analysed using Nacsport. The characteristics of these tackles were summarised (n, %) and a binomial logistic regression was used to identify associations between these characteristics and head contact, for the ball carrier, primary tackler and adjust tackler. Tacklers had head contact more often than the ball carrier and the likelihood of head contact was higher at U13 than at U15 and U18 for the tackler, but there were no age-related differences for the ball carrier. Tacklers had a lower likelihood of head contact when in motion and tackling from the side. The findings of this study suggest that tackles where the first point of contact is the head & neck are not being penalised and that the likelihood of ball carrier head contact is higher when there is more than one tackler. This study reinforces England Rugby's decision to trial a reduction in tackle height to below the armpit for age-grade rugby and provides evidence that the tap tackle should be banned and that the number of tacklers should be limited to one at U13 and U15 and to two at U18.

6.1 Introduction

In rugby, the tackle is a dynamic and high-impact collision between two or more players (Hendricks, Jordaan and Lambert, 2012), the success of which has been associated with a positive team outcome (Hendricks et al., 2018b). The tackle has consistently been shown to be both the most common contact event (chapter 5) (Roberts et al., 2015; Fuller et al., 2007a) and the event associated with the most injuries and time lost due to injury (chapter 4) (Burger et al., 2020) at all levels of the game. Within English schoolboy rugby, the tackle is responsible for around 55% of all injuries (chapter four) (Palmer-Green et al., 2013; Barden and Stokes, 2018). Furthermore, tackles are responsible for the majority of concussions in both schoolboy (59%) (chapter four) and professional (53%) (Cross, Kemp, Smith, Trewartha and Stokes, 2016) rugby matches. The tackle has, therefore, been suggested as a key focus of injury and concussion prevention interventions (Tucker et al., 2017b).

Numerous studies have used match analysis to provide quantifiable data on rugby matches and the events within them, but these have primarily focused on performance in a professional setting. A study into tackle technique and concussion within professional rugby highlighted that the tackler is at a greater risk of concussion than the ball carrier (Cross et al., 2019). In this study the risk of concussion increased when a player was accelerating into the tackle, at high speed or if their head made contact with an opposing player's head. Research by Tucker et al. (2017b) found that head injury risk was greater for active shoulder tackles and for those coming from the front or at high speed. It was recommended that tackle height should be lowered and that tacklers adopt a bent at the waist body position to improve safety. Similar findings, with regard to tackle direction, were found by Seminati, Cazzola, Trewartha, Williams and Preatoni (2017). Dominant shoulder tackles were shown to produce the greatest forces, decreasing by 3% when tackling diagonally and by 10% when tackling laterally. This study highlighted the importance of tackling at an offset angle and decrease deficiencies in tackles using the non-dominant side, in order to reduce the risk of injury.

Research into the characteristics of tackles within youth rugby is limited, but investigation into tackles within a South African youth tournament found that tackles with better technique were less likely to result in injury (Burger et al., 2016) and that tackles where the tackler made contact with the head and neck of the ball carrier were more likely to result injury for both the tackler and ball carrier (Burger et al., 2017). The ball carrier and primary tackler (predominantly the first defender to make contact or the defender who makes the most significant contact) (England Rugby, 2018a) were the focus of these studies. So far, the characteristics of the adjust tackler (a tackler who joins the tackle prior to the tackle being completed, but after a primary tackle or contact has been made) (England Rugby, 2018a) have not been investigated.

In a review of tackle research by Burger et al. (2020), it was concluded that a combination of progressive tackle technique training, law change and education are more likely to reduce injury risk than any of these methods individually. Understanding the characteristics of tackles at different age groups will aid the development of such population-specific interventions. It is important that head contacts (any clear head contact occurring in the tackle to either the carrier or tacklers) (England Rugby, 2018a) and the tackle characteristics associated with them are understood, given that the majority of head injuries are caused during tackles with head contact (Davidow et al., 2018) and that head contact has been associated with both injury and concussion. This study will investigate the characteristics of both primary and adjust tackles in an English schoolboy setting, for the under-13 (U13), under-15 (U15) and under-18 (U18) age groups. The characteristics of tackles that are associated with head contact will then be identified in the context of the ball carrier, primary tackler and adjust tackler.

6.2 Methods

6.2.1 Study Design & Setting

This is a cross-sectional descriptive study of tackle characteristics and their association with head contact within an English secondary school setting.

6.2.2 Study Size

In total, 8017 tackles (6774 primary, 1243 adjust) were analysed across each of the three age groups (U13, U15 and U18). Tackle footage was captured from 56 teams, from 43 schools (table 6.1).

Table 6.1: An overview of the tackle analysis data collected.

	Under-13	Under-15	Under-18	Overall
Tackles				
Primary, n	1995	2000	2779	6774
Adjust, n	244	297	702	1243
Total, n	2239	2297	3481	8017
Participants				
Matches, n	10	11	16	37
Teams, n	19	16	21	56
Schools, n	19	16	21	43

6.2.3 Participants

Match footage was collected over two seasons, from September 2017 to April 2019. Matches from schools who were involved with England Rugby’s Youth Rugby Injury

Surveillance Project were filmed. All footage collected was from boys' teams in the U13, U15 and U18 age groups.

Ethical approval for the study was obtained from the Research Ethics Approval Committee for Health (REACH). Before any data was collected, player (APPENDIX E), parent (APPENDIX F) and staff (APPENDIX G) information sheets, player assent (APPENDIX H) forms and parental (APPENDIX I) and staff (APPENDIX J) consent forms were sent electronically, using Bristol Online Surveys (Online Surveys, 2021). Opposition (APPENDIX K) and match official (APPENDIX L) consent was gained by the company filming the matches.

6.2.4 Variables

The definitions used for match analysis were based on the consensus on a video analysis framework of descriptors and definitions by the rugby union video analysis consensus group (Hendricks et al., 2020) and England Rugby's Tackle Trial Operational Definitions Manual (England Rugby, 2018a). Where a suitable definition could not be found, an original definition was created. Definitions for tackle characteristics can be seen in table 6.2. An unknown category was also included for each of the tackle characteristics.

Table 6.2: Tackle characteristic definitions.

Characteristic	Definition
Tackle	
Primary	The primary tackler in the tackle. Predominantly the 1st defender to make contact or the defender who makes the most significant contact.
Adjust	Any tackler(s) who joins the tackle (prior to the tackle being complete) once a primary tackle / contact has been made.
Field Position	
Vertical	The field was divided into vertical sections between the two try-lines. A representing the area between the attacking team's 22m line and own try-line, B the area between attacking team's 22m line and half-way line, C the area between the opposition 22m line and half-way line and D representing the area between the opposition 22m and try-line.
Horizontal	The field was divided into horizontal quadrants between the two touch lines with quadrant 1 representing the area furthest away from the camera, and quadrant 4 representing the area closest to the camera view.
Number of Tacklers	
Number of Tacklers	The number of defenders (1/2/>2) actively attempting to stop or impede the ball carrier (player carrying the ball) whether the ball carrier was brought to ground or not. Tacklers are counted until the ball carrier is brought to ground.
Outcome	
Successful	When a tackle break does not occur, and either player goes to ground or the ball carrier is held up and cannot progress further, whether they offload the ball or not.
Tackle Break	The ball carrier successfully penetrates the attempted tackle and continues to advance.
Incomplete	The tackler makes contact, but actively decides not to complete the tackle. This is common after the ball is offloaded.
Unsuccessful (Missed)	There is no meaningful contact and the tackler fails to tackle the ball carrier, thus allowing the ball carrier to advance during open play.
Style	
Active	First contact is with the tackler's shoulder, and the tackler drives or attempts to drive the ball carrier backwards towards the opposition try line.
Passive	The tackler does not drive or attempt to drive the ball carrier backwards towards the opposition try line.
Smother	Tackler uses chest and wraps both arms around ball carrier.
Tap	Tackler trips ball carrier with hand on lower limb below the knee.
Fended	
Yes	Ball carrier provided a light to moderate (eg, swat or slap technique) or strong (eg, push technique) fend.
No	Ball carrier provided no fend.
Direction	
Front	Tackler makes contact in front of the ball carrier (315-0-45 degrees).
Side	Tackler makes contact with the ball carrier's side (315-225; 135-45 degrees).
Back	Tackler makes contact with the ball carrier's from behind (225-180-135 degrees).

Table 6.2 (Cont'd): Tackle characteristic definitions.

Characteristic	Definition
First Point of Contact	
Head & Neck	Initial contact is made on any part of the head or neck of the ball carrier by the tackler or adjust tackler.
Shoulder & Armpit	Initial tackle contact is made above the line of the armpit and below the top of the shoulders.
Torso	Initial contact is made on the torso - above the mid-point line of the hips and below the line of the armpits.
Upper Leg	Initial contact is made on the Upper leg - above the mid-point of the knee and below the mid-point of the hips.
Lower Leg	Initial contact is made on the Lower leg - from the foot unto the mid-point of the knee.
Speed	
Static	If a player has his feet planted in the final moments before contact, then he is static.
In Motion	If a player is in motion (walking / jogging) but not at 'high speed' going into contact.
High Speed	If a player is at fast pace or sprinting.
Body Position	
Upright	The tackler / carrier are upright (no bend at the waist / hips) at the point of contact, maybe slightly bent at knees (if a line is drawn outwards from the chest, it would not intersect the floor).
Bent	The tackler / carrier are bent at the waist at the point of contact (if a line is drawn outwards from the chest, it would intersect the floor).
Diving	The tackler / carrier is the process of diving at the point of contact.
Head Contact	
Head Contact	Any clear head contact occurring in the tackle to either the carrier or tacklers. If there is no head contact made, no head contact must be coded to the relevant player. Every tackler and carrier should have either a head to body part code or a no head contact code. Head to body part codes are: No Head Contact, To Head, To Arm, To Torso, To Hip, To Upper Leg, To Knee, To Lower Leg, To Ground, To Equipment, To Player.
Equipment	Head to equipment includes any contact with post protectors, flags or the ball.
Player	The ball carrier's head makes contact with a player other than the tackler.
Penalisation	
Lift	Penalised by the referee for allowing the ball carrier to go beyond horizontal.
High	Penalised by the referee for contact being high.
Elbow	A tackler is penalised by the referee for illegally using his elbow / forearm.
No Arms	A tackler is penalised by the referee as shoulder only used to make the tackle - no use of arms.
Air	Penalised by the referee for a defender making contact with the carrier in the air.

6.2.5 Data Collection

Footage for the U13 age group was collected during the 2017/18 season and footage for the U15 and U18 age groups during the 2018/19 season. Camera operators were instructed to follow the ball, but to zoom in to contact events where possible, and to film from as high as possible at the side of the pitch. Within a previous study (chapter five), matches were analysed for match events. During this analysis, tackles were identified and subsequently used for analysis within this study. Tackles from 37 matches (U13: 10, U15: 11, U18: 16) were analysed.

6.2.6 Tackle Analysis

All analysis was carried out on Nacsport Pro Plus Match Analysis Software (chapter three) (Nacsport, 2021). A coding window was designed (figure 3.2) and tackles which had previously been identified were loaded in the software. Tackle characteristics were added using “descriptors” and, where there was more than one tackler, an adjust tackle “category” was added and the process was repeated. The software allowed the coder to pause, rewind and watch the footage in slow motion.

6.2.6.1 Pre-Coding Validation

Two coders were used for the analysis of tackles. Before any analysis was conducted both coders were required to code 30 tackles which had previously been coded by an expert coder (>10 years of experience). They were required to achieve 90% agreement with the expert coder for each characteristic before being allowed to collect data. This was done to ensure that they were at a standard set by an expert, before analysing the tackles used within this thesis. However, the emphasis was placed on the post-coding validation. The focus for this was on reliability and repeatability, due to the fact that there were two experienced coders.

6.2.6.2 Inter-Rater Reliability

Once the data collection had been completed, both coders analysed 60 tackles from each age group and inter-rater reliability was assessed and interpreted using Cohen’s kappa

(Cohen, 1960), where agreement was deemed either slight (0-0.20), fair (0.21-0.40), moderate (0.41-0.6), substantial (0.61-0.8) or almost perfect (>0.8). The kappa score was calculated for each tackle characteristic and a mean was taken for each age group and for overall. When there was 100% agreement on a single characteristic, the kappa statistic could not be calculated, so this was given a score of 1. A kappa of >0.8 was set for validation, to ensure that any coding was almost perfect. The overall score for inter-rater reliability was 0.8 - substantial, but just short of almost perfect.

For individual characteristics within each age group which fell below the required kappa score, it was checked to see whether the overall score for that characteristic was affected. If the agreement was substantial, no further investigation was conducted. Where the agreement was moderate or below, this was investigated further. This was the case for direction, ball carrier head contact and penalisation. For direction, there was agreement between Coder 1 and Coder 2 in 143/180 cases. The only disagreements were where one Coder considered a tackle a “side” tackle and the other considered it a “front” or “back” tackle. It was decided that this characteristic would be included as there was 79% agreement, but the kappa score should be considered when interpreting the results for this characteristic. For ball carrier head contact, there was agreement in 148/180 (82%) cases. It was decided that, for statistical analysis, head contact would only be considered “yes” or “no”. For penalisation, there was 99% accuracy (178/180). When calculating kappa scores for characteristics with minimal variability, mistakes or disagreements cause the score to drop significantly. Whilst this is the case, it was decided that penalisation would be described, but would not be included within the statistical analysis.

6.2.6.3 Intra-Rater Reliability

An intra-rater analysis was also completed using the same method, with Coder 1 and Coder 2 re-analysing (>1 month from original analysis) 30 tackles at each age group. The overall intra-rater reliability was 0.91, almost perfect, for both coders.

6.2.7 Statistical Analysis

Once the tackles within a match had been analysed, they were exported as a Microsoft Excel file and cleaned, which included checking that there was no missing data and that each of the characteristics were in the correct column. Exported data files from each match were then merged into a master spreadsheet for analysis, where totals (n) and proportions (%) were calculated for each characteristic. This was done for both primary and adjust tackles, for all three age groups.

Based on the findings of the validation, head contact, for both the ball carrier and tackler, were re-coded into “yes”, “no” or “unknown”. To determine whether each of the characteristics (age, quarter, field position - vertical, field position - horizontal, number of tacklers, outcome, style, direction, first point of contact (FPOC), speed - carrier, speed - tackler, body position - carrier, body position - tackler) were associated with head contact, a binomial logistic regression was conducted on IBM SPSS statistics 25. In total, 12 models were created (table 6.5); these were for the ball carrier, primary tackler and adjust tackler at each age groups (U13, U15, U18) and for all data (overall). As ball carrier head contact would have been captured a second time when an adjust tackle was analysed, only ball carrier head contact data from primary tackles was used. Tackles with unknown head contact were excluded from the models. Odds ratios and p-values were used to interpret the data. As 12 models were created, a p-value of <0.05 was deemed too likely to result in type 1 error, whilst using a Bonferroni correction was deemed too conservative and likely to result in type 2 error. For this reason, significance was set at a more robust p-value; results where $p<0.01$ were considered significant.

To test that the model was not a bad fit a Hosmer-Lemeshow test was used, with $p>0.05$ being considered a lack of evidence of poor fit. A Receiver Operating Characteristic (ROC) curve was used as a measure of a useful predictive model, with values of 0.7 to 0.8 being considered “acceptable”, 0.8 to 0.9 being considered “excellent” and >0.9 “outstanding” (Mandrekar, 2010).

6.3 Results

A spread of tackles was analysed from each quarter (Q1: 26%, Q2: 24%, Q3: 25%, Q4: 25%). Overall, 6% of data was unknown, with the most data missing being for FPOC (14%), style (15%), tackler head contact (23%) and ball carrier head contact (28%). Examples of footage resulting in unknown head contact can be found at APPENDIX O.

6.3.1 Tackle Characteristics

Most tackles involved a single tackler (U13: 85%; U15: 83%; U18: 73%), but the proportion of tackles with >1 tackler was lower at U13 (11%) and U15 (14%) than at U18 (24%). The success rate of primary tackles was higher when players were older (U13: 56%; U15: 62%; U18: 75%), but the success rate for adjust tackles was similar at all age groups (93 to 95%). Successful, break and incomplete tackles accounted for 81% of U13 and U15 tackles and 87% of U18 tackles. Passive tackles were the most common style of tackle at all age groups (U13: 61%; U15: 59%; U18: 68%); the proportion of passive tackles was even higher for adjust tackles (U13: 87%; U15: 77%; U18: 79%). In the majority of cases the ball carrier did not fend the tackler (U13: 6%; U15: 8%; U18: 9%) (table 6.3).

Most tackles came from the side at all age groups (U13: 79%; U15: 75%; U18: 67%), however the proportion coming from the front was higher at older age groups (U13: 10%; U15: 15%; U18: 20%). Adjust tackles came from the front more commonly than primary tackles (U13: 21%; U15: 19%; U18: 25%). The most common first point of contact (FPOC) on the ball carrier was the torso for all age groups (U13: 59%; U15: 46%; U18: 43%). Adjust tacklers (U13: 4%; U15: 6%; U18: 9%) made contact with the head & neck of the ball carrier at least twice as often as primary tacklers (U13: 2%; U15: 3%; U18: 4%). The proportion adjust of tacklers (U13: 38%; U15: 38%; U18: 32%) tackling at the height of the armpit or above was also at least twice that of primary tacklers (U13: 10%; U15 17%; U18: 16%).

The proportion of primary tacklers categorised as either in motion or at high speed was greater at older age groups (U13: 38%; U15: 46%; U18: 50%). Adjust tacklers were static (U13: 86%; U15: 74%; U18: 57%) more often than primary tacklers (U13: 59%; U15: 51%; U18: 46%). The speed of ball carriers was similar at all age groups, with between 85% and 87% categorised as either in motion or at high speed. The most common body position for primary tacklers was upright at U13 and U15 (U13: 50%; U15: 44%; U18: 33%) and bent at U18 (U13: 27%; U15: 32%; U18: 39%). The ball carrier was upright in the majority of tackles at all age groups (U13: 87%; U15: 81%; U18: 74%). In total, six U13 tackles (five high tackle, one unknown), 13 U15 tackles (seven high tackle, one illegal lift, one no arms, four unknown) and 71 U18 tackles (two in air, 19 high tackle, 50 unknown) were penalised. This resulted in one card being awarded per age group; none of which were red cards.

Table 6.3: The characteristics of primary and adjust tackles.

	Under-13		**Under-15**		**Under-18**		**Overall**	
	Primary, n (%)	**Adjust, n (%)**	**Primary, n (%)**	**Adjust, n (%)**	**Primary, n (%)**	**Adjust, n (%)**	**Primary, n (%)**	**Adjust, n (%)**
Field Position - Horizontal								
1	411 (20.6)	45 (18.4)	492 (24.6)	52 (17.5)	545 (19.6)	103 (14.7)	1448 (21.4)	200 (16.1)
2	560 (28.1)	57 (23.4)	495 (24.8)	84 (28.3)	736 (26.5)	203 (28.9)	1791 (26.4)	344 (27.7)
3	603 (30.2)	91 (37.3)	513 (25.7)	96 (32.3)	790 (28.4)	211 (30.1)	1906 (28.1)	398 (32.0)
4	403 (20.2)	51 (20.9)	476 (23.8)	64 (21.5)	691 (24.9)	184 (26.2)	1570 (23.2)	299 (24.1)
Try	16 (0.8)	0 (0)	23 (1.2)	1 (0.3)	15 (0.9)	1 (0.1)	54 (0.8)	2 (0.2)
Unknown	2 (0.1)	0 (0)	1 (0.1)	0 (0)	2 (0.1)	0 (0)	5 (0.1)	0 (0)
Field Position - Vertical								
A	287 (14.4)	32 (13.1)	307 (15.4)	49 (16.5)	400 (14.4)	148 (21.1)	994 (14.7)	229 (18.4)
B	655 (32.8)	86 (35.2)	674 (33.7)	98 (33.0)	938 (33.8)	221 (31.5)	2267 (33.5)	405 (32.6)
C	672 (33.7)	73 (29.9)	627 (31.4)	89 (30.0)	976 (35.1)	233 (33.2)	2275 (33.6)	395 (31.8)
D	363 (18.2)	53 (21.7)	368 (18.4)	60 (20.2)	448 (16.1)	99 (14.1)	1179 (17.4)	12 (17.1)
Try	16 (0.8)	0 (0)	23 (1.2)	1 (0.3)	15 (0.5)	1 (0.1)	54 (0.8)	2 (0.2)
Unknown	2 (0.1)	0 (0)	1 (0.1)	0 (0)	2 (0.1)	0 (0)	5 (0.1)	0 (0)
No of Tacklers								
1	1694 (84.9)	-	1664 (83.2)	-	2014 (72.5)	-	5372 (79.3)	-
2	210 (10.5)	208 (85.2)	259 (13.0)	261 (87.9)	605 (21.8)	602 (85.8)	1074 (15.9)	1071 (86.2)
>2	15 (0.8)	32 (13.1)	17 (0.9)	36 (12.1)	57 (2.1)	100 (14.2)	89 (1.3)	168 (13.5)
Unknown	76 (3.8)	4 (1.6)	60 (3.0)	0 (0)	103 (3.7)	0 (0)	239 (3.5)	4 (0.3)
Outcome								
Successful	1124 (56.3)	229 (93.9)	1235 (61.8)	277 (93.3)	2087 (75.1)	664 (94.6)	4446 (65.6)	1170 (94.1)
Tackle Break	203 (10.2)	9 (3.7)	141 (7.1)	8 (2.7)	130 (4.7)	9 (1.3)	474 (7.0)	26 (2.1)
Incomplete	288 (14.4)	5 (2.0)	244 (12.2)	5 (1.7)	187 (6.7)	5 (0.7)	719 (10.6)	15 (1.2)
Unsuccessful (Missed)	346 (17.3)	1 (0.4)	358 (17.9)	6 (2.0)	304 (10.9)	23 (3.3)	1008 (14.9)	30 (2.4)
Unknown	34 (1.7)	0 (0)	22 (1.1)	1 (0.3)	71 (2.6)	1 (0.1)	127 (1.9)	2 (0.2)
Style								
Active	199 (10.0)	18 (7.4)	269 (13.5)	32 (10.8)	434 (15.6)	80 (11.4)	902 (13.3)	130 (10.5)
Passive	1219 (61.1)	211 (86.5)	1186 (59.3)	228 (76.8)	1891 (68.0)	553 (78.8)	4296 (63.4)	992 (79.8)
Smother	99 (5.0)	14 (5.7)	104 (5.2)	29 (9.8)	128 (4.6)	52 (7.4)	331 (4.9)	95 (7.6)
Tap	24 (1.2)	0 (0)	30 (1.5)	1 (0.3)	40 (1.4)	4 (0.6)	94 (1.4)	5 (0.4)
Unknown	454 (22.8)	1 (0.4)	411 (20.6)	7 (2.4)	286 (10.3)	13 (1.9)	1151 (17.0)	21 (1.7)
Fended								
Yes	115 (5.8)	2 (0.8)	164 (8.2)	9 (3.0)	245 (8.8)	29 (4.1)	524 (7.7)	40 (3.2)
No	1831 (91.8)	241 (98.8)	1769 (88.5)	286 (96.3)	2343 (84.3)	666 (94.9)	5943 (87.7)	1193 (96.0)
Unknown	49 (2.5)	1 (0.4)	67 (3.4)	2 (0.7)	191 (6.9)	7 (1.0)	307 (4.5)	10 (0.8)
Direction								
Front	201 (10.1)	52 (21.3)	307 (15.4)	57 (19.2)	555 (20.0)	176 (25.1)	1063 (15.7)	285 (22.9)
Side	1575 (78.9)	174 (71.3)	1501 (75.1)	217 (73.1)	1855 (66.8)	462 (65.8)	4931 (72.8)	853 (68.6)
Back	143 (7.2)	15 (6.1)	114 (5.7)	20 (6.7)	201 (7.2)	59 (8.4)	458 (6.8)	94 (7.6)
Unknown	76 (3.8)	3 (1.2)	78 (3.9)	3 (1.0)	168 (6.0)	5 (0.7)	322 (4.8)	11 (0.9)
First Point of Contact								
Head & Neck	40 (2.0)	10 (4.1)	55 (2.8)	17 (5.7)	100 (3.6)	61 (8.7)	195 (2.9)	88 (7.1)
Shoulder & Armpit	161 (8.1)	83 (34.0)	281 (14.1)	97 (32.7)	345 (12.4)	164 (23.4)	787 (11.6)	344 (27.7)
Torso	1175 (58.9)	121 (49.6)	909 (45.5)	120 (40.4)	1196 (43.0)	340 (48.4)	3280 (48.4)	581 (46.7)
Upper Leg	287 (14.4)	19 (7.8)	394 (19.7)	33 (11.1)	598 (21.5)	52 (7.4)	1279 (18.1)	104 (8.4)
Lower Leg	46 (2.3)	1 (0.4)	57 (2.9)	4 (1.3)	112 (4.0)	12 (1.7)	215 (3.2)	17 (1.4)
Unknown	286 (14.3)	10 (4.1)	304 (15.2)	26 (8.8)	428 (15.4)	73 (10.4)	1018 (15.0)	109 (8.8)
Speed - Tackler								
Static	1176 (58.9)	209 (85.7)	1014 (50.7)	220 (74.1)	1264 (45.5)	400 (57.0)	3454 (51.0)	829 (66.7)
In Motion	647 (32.4)	33 (13.5)	793 (39.7)	69 (23.2)	1199 (43.1)	285 (40.6)	2639 (39.0)	387 (31.1)
High Speed	109 (5.5)	1 (0.4)	121 (6.1)	4 (1.3)	192 (6.9)	15 (2.1)	422 (6.2)	20 (1.6)
Unknown	63 (3.2)	1 (0.4)	72 (3.6)	4 (1.3)	124 (4.5)	2 (0.3)	259 (3.8)	7 (0.6)
Speed - Ball Carrier								
Static	226 (11.3)	52 (21.3)	233 (11.7)	44 (14.8)	227 (8.2)	78 (11.1)	686 (10.1)	174 (14.0)
In Motion	1473 (73.8)	185 (75.8)	1449 (72.5)	237 (79.8)	2051 (73.8)	583 (83.0)	4973 (73.4)	1005 (80.9)
High Speed	233 (11.7)	6 (2.5)	246 (12.3)	12 (4.0)	377 (13.6)	39 (5.6)	856 (12.6)	57 (4.6)
Unknown	63 (3.2)	1 (0.4)	72 (3.6)	4 (1.3)	124 (4.5)	2 (0.3)	259 (3.8)	7 (0.6)
Body Position - Tackler								
Upright	1004 (50.3)	138 (56.6)	882 (44.1)	154 (51.9)	918 (33.0)	368 (52.4)	2804 (41.4)	660 (53.1)
Bent	529 (26.5)	95 (38.9)	634 (31.7)	116 (39.1)	1076 (38.7)	258 (36.8)	2239 (33.1)	469 (37.7)
Diving	372 (18.6)	8 (3.3)	386 (19.3)	18 (6.1)	614 (22.1)	58 (8.3)	1372 (20.3)	84 (6.8)
Unknown	90 (4.5)	3 (1.2)	98 (4.9)	9 (3.0)	171 (6.2)	18 (2.6)	359 (5.3)	30 (2.4)
Body Position - Ball Carrier								
Upright	1737 (87.1)	183 (75.0)	1622 (81.1)	214 (72.1)	2045 (73.6)	436 (62.1)	5404 (79.8)	833 (67.0)
Bent	145 (7.3)	56 (23.0)	256 (12.8)	69 (23.2)	507 (18.2)	222 (31.6)	908 (13.4)	347 (27.9)
Diving	23 (1.2)	2 (0.8)	24 (1.2)	5 (1.7)	56 (2.0)	26 (3.7)	103 (1.5)	33 (2.7)
Unknown	90 (4.5)	3 (1.2)	98 (4.9)	9 (3.0)	171 (6.2)	18 (2.6)	359 (5.3)	30 (2.4)

6.3.2 Head Contact

A higher proportion of U13 (47%) primary tackles resulted in tackler head contact than at U15 (43%) and U18 (43%); this proportion was even higher for adjust tackles at U13 (55%) and U15 (50%). Both primary (U13: 51%; U15: 40%; U18: 29%) and adjust tacklers (U13: 52%; U15: 45%; U18: 33%) had head contact with the torso most often. Primary and adjust tackles resulted in tackler head-to-head contact in 4-6% of tackles, with the exception of U18 adjust tacklers who made head-to-head contact in 12% of tackles (table 6.4).

With the exception of U18 adjust tacklers, the ball carrier (U13: 14%; U15: 17%; U18: 22%) had head contact less often than both primary (U13: 47%; U15: 43%; U18: 43%) and adjust (U13: 55%; U15: 50%; U18: 35%) tacklers. Ball carrier head contact was more common during adjust tackles (U13: 28%; U15: 31%; U18: 36%) than primary tackles (U13: 14%; U15: 17%; U18: 22%). Other than during U13 adjust tackles (shoulder: 30%) the ball carrier had head contact with a player other than the tackler most often (26-40%). Head-to-head contact was more common for the ball carrier than the tackler, except during U18 adjust tackles.

Table 6.4: Tackler and ball carrier head contact during primary and adjust tackles.

	Under-13		**Under-15**		**Under-18**		**Overall**	
	Primary, n (%)	**Adjust, n (%)**	**Primary, n (%)**	**Adjust, n (%)**	**Primary, n (%)**	**Adjust, n (%)**	**Primary, n (%)**	**Adjust, n (%)**
Tackler								
No	688 (34.5)	42 (17.2)	753 (37.7)	70 (23.6)	841 (30.0)	257 (36.6)	2282 (33.7)	369 (29.7)
Yes	941 (47.2)	134 (54.9)	858 (42.9)	148 (49.8)	1192 (42.9)	246 (35.0)	4492 (66.3)	874 (70.3)
- Head	57 (6.1)	8 (6.0)	36 (4.2)	6 (4.1)	67 (5.6)	29 (11.8)	160 (2.4)	43 (3.5)
- Shoulder	117 (12.4)	38 (28.4)	114 (13.3)	32 (21.6)	152 (12.8)	43 (17.5)	383 (5.7)	113 (9.1)
- Arm	22 (2.3)	1 (0.7)	24 (2.8)	5 (3.4)	84 (7.0)	20 (8.1)	130 (1.9)	26 (2.1)
- Torso	481 (51.1)	70 (52.2)	343 (40.0)	66 (44.6)	345 (28.9)	80 (32.5)	1169 (17.3)	216 (17.4)
- Hip	126 (13.4)	8 (6.0)	141 (16.4)	8 (5.4)	298 (25.0)	35 (14.2)	565 (8.3)	51 (4.1)
- Upper Leg	93 (9.9)	6 (4.5)	149 (17.4)	18 (12.2)	128 (10.7)	10 (4.1)	370 (5.5)	34 (2.7)
- Knee	4 (0.4)	0 (0)	2 (0.2)	0 (0)	29 (2.4)	5 (2.0)	35 (0.5)	5 (0.4)
- Lower Leg	27 (2.9)	0 (0)	35 (4.1)	2 (1.4)	59 (4.9)	3 (1.2)	121 (1.8)	5 (0.4)
- Ground	11 (1.2)	0 (0)	10 (1.2)	4 (2.7)	18 (1.5)	4 (1.6)	39 (0.6)	8 (0.6)
- Equipment	0 (0)	1 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.1)
- Other Player	3 (0.3)	2 (1.5)	4 (0.5)	7 (4.7)	12 (1.0)	17 (6.9)	19 (0.3)	26 (2.1)
Unknown	366 (18.3)	68 (27.9)	389 (19.5)	79 (26.6)	746 (26.8)	199 (28.3)	1501 (22.2)	346 (27.8)
Ball Carrier								
No	1313 (65.8)	77 (31.6)	1274 (63.7)	104 (35.0)	1506 (54.2)	246 (35.1)	4093 (60.4)	427 (34.4)
Yes	283 (14.2)	69 (28.3)	329 (16.5)	91 (30.7)	599 (21.6)	254 (36.2)	2681 (39.6)	816 (65.6)
- Head	56 (19.8)	9 (13.0)	37 (11.2)	7 (7.7)	66 (11.0)	28 (11.0)	159 (2.3)	44 (3.5)
- Shoulder	52 (18.4)	21 (30.4)	74 (22.5)	12 (13.2)	96 (16.0)	47 (18.5)	222 (3.3)	80 (6.4)
- Arm	33 (11.7)	7 (10.2)	54 (16.4)	13 (14.3)	78 (13.0)	28 (11.0)	165 (2.4)	48 (3.9)
- Torso	8 (2.8)	6 (8.7)	14 (4.3)	12 (13.2)	44 (7.3)	21 (8.3)	66 (1.0)	39 (3.1)
- Hip	1 (0.4)	0 (0)	0 (0)	1 (1.1)	3 (0.5)	3 (1.2)	4 (0.1)	4 (0.3)
- Upper Leg	1 (0.4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0)	0 (0)
- Knee	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.2)	0 (0)	1 (0)	0 (0)
- Lower Leg	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.4)	0 (0)	1 (0.1)
- Ground	52 (18.4)	8 (11.6)	64 (19.5)	10 (11.0)	120 (20.0)	32 (12.6)	236 (3.5)	50 (4.0)
- Equipment	0 (0)	0 (0)	1 (0.3)	0 (0)	2 (0.3)	0 (0)	3 (0)	0 (0)
- Other Player	80 (28.3)	18 (26.1)	85 (25.8)	36 (39.5)	189 (31.6)	94 (37.0)	354 (5.2)	148 (11.9)
Unknown	399 (20.0)	98 (40.1)	397 (19.9)	102 (34.3)	674 (24.3)	202 (28.7)	1470 (21.7)	402 (32.3)

6.3.3 Statistical Models

The Hosmer-Lemeshow test showed a lack of evidence of poor fit for all models ($p>0.05$). With the exception of the overall and U18 adjust tackler models, which were considered acceptable, 10 of the 12 models were considered excellent (table 6.5).

Table 6.5: An overview of the statistical models used to identify tackle characteristics' association with head contact.

	Tackles In Model, n	Hosmer-Lemeshow, p	Evidence of Poor Fit	ROC, AUC	Usefulness
Under-13					
Ball Carrier	1136	0.128	No	0.879	Excellent
Primary Tackler	1174	0.519	No	0.851	Excellent
Adjust Tackler	171	0.191	No	0.844	Excellent
Under-15					
Ball Carrier	1179	0.755	No	0.867	Excellent
Primary Tackler	1188	0.132	No	0.832	Excellent
Adjust Tackler	205	0.062	No	0.847	Excellent
Under-18					
Ball Carrier	1744	0.413	No	0.844	Excellent
Primary Tackler	1678	0.557	No	0.821	Excellent
Adjust Tackler	468	0.916	No	0.784	Acceptable
Overall					
Ball Carrier	4059	0.214	No	0.852	Excellent
Primary Tackler	4040	0.504	No	0.821	Excellent
Adjust Tackler	844	0.950	No	0.794	Acceptable

6.3.4 Characteristics Associated With Head Contact: Ball Carrier

When there were two tacklers, rather than one, the ball carrier was significantly more likely (overall: OR=4.22; U13: OR=5.23; U15: OR=4.67; U18: OR=3.93; $p<0.01$) to have head contact. At U18, the likelihood of ball carrier head contact was even higher (OR=15.1, $p<0.01$) when there were more than two tacklers. It was significantly more likely that there would be head contact when the tackle was successful, when compared to incomplete tackles (OR=0.12, $p<0.01$), tackle breaks (OR=0.12, $p<0.01$) and unsuccessful (missed) tackles (OR=0.03, $p<0.01$). Overall, tap tackles were significantly more likely to result in head contact than active tackles (OR=4.49, $p<0.01$), with U18 players having the highest likelihood (OR=10.6, $p<0.01$). In total, there were 99 tap tackles (head contact: 13, no head contact: 80, unknown: 6). Of the 13 resulting in head contact, 7 (54%) were to the ground and 5 (38%) were with a player other than the tackler. Tackles from the side (OR=0.53, $p<0.01$) and back (OR=0.58, $p<0.01$) were less likely to result in head contact than those from the front. When the ball carrier fended a tackle, they were no less likely to have head contact. When the FPOC was at the height of the head & neck, it was significantly more likely to result in ball carrier head contact than any other FPOC (OR<0.1, $p<0.01$). At U18, when the tackler was in motion rather than static, this resulted in a decreased likelihood of ball carrier head contact (OR=0.63, $p<0.01$). Ball carrier speed had no effect on head contact, but the bent ball carrier position was more likely to result in head contact than the upright body position (OR=2.4, $p<0.01$). Overall, there were no significant differences between age groups for the ball carrier (table 6.6).

Table 6.6: Odds ratios for tackle characteristics' association to ball carrier head contact.

	Under-13		Under-15		Under-18		Overall	
Characteristic	**p**	**OR (95% CI)**	**p**	**OR (95% CI)**	**p**	**OR (95% CI)**	**p**	**OR (95% CI)**
Age	-	-	-	-	-	-	0.48	-
U13 (Reference)	-	-	-	-	-	-	-	-
U15	-	-	-	-	-	-	0.23	-
U18	-	-	-	-	-	-	0.47	-
Quarter	0.18	-	0.39	-	0.09	-	0.52	-
Q1 (Reference)	-	-	-	-	-	-	-	-
Q2	0.12	-	0.16	-	0.12	-	0.53	-
Q3	0.04	-	0.14	-	0.01	-	0.96	-
Q4	0.51	-	0.61	-	0.08	-	0.36	-
Field - Vertical	1.00	-	**<0.01**	-	0.20	-	0.27	-
A (Reference)	-	-	-	**1.00**	-	-	-	-
B	0.82	-	0.33	-	0.30	-	0.88	-
C	0.76	-	**<0.01**	**0.43 (0.25-0.74)**	0.13	-	0.77	-
D	0.97	-	0.72	-	0.04	-	0.22	-
Try	1.00	-	0.18	-	-	-	0.20	-
Field - Horizontal	0.82	-	0.20	-	**<0.01**	-	**<0.01**	-
1 (Reference)	-	-	-	-	-	**1.00**	-	**1.00**
2	0.40	-	0.06	-	0.18	-	0.02	-
3	0.66	-	0.25	-	0.03	-	0.02	-
4	0.44	-	0.06	-	**<0.01**	**2.08 (1.38-3.14)**	**<0.01**	**1.64 (1.25-2.15)**
No of Tacklers	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
1 (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
2	**<0.01**	**5.23 (3.31-8.26)**	**<0.01**	**4.67 (3.03-7.21)**	**<0.01**	**3.93 (2.97-5.21)**	**<0.01**	**4.22 (3.44-5.17)**
>2	0.31	-	0.47	-	**<0.01**	**15.1 (6.16-37.1)**	**<0.01**	**8.14 (4.10-16.2)**
Outcome	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
Success (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
Incomplete	**<0.01**	**0.06 (0.02-0.17)**	**<0.01**	**0.06 (0.02-0.17)**	**<0.01**	**0.06 (0.01-0.28)**	**<0.01**	**0.12 (0.07-0.20)**
Tackle Break	**<0.01**	**0.09 (0.03-0.25)**	**<0.01**	**0.12 (0.05-0.30)**	**<0.01**	**0.12 (0.06-0.25)**	**<0.01**	**0.12 (0.08-0.19)**
Unsuccessful (Missed)	0.01	-	**<0.01**	**0.02 (0-0.17)**	**<0.01**	**0.02 (0-0.15)**	**<0.01**	**0.03 (0.01-0.10)**
Style	**<0.01**	-	**<0.01**	-	0.02	-	**<0.01**	-
Active (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
Passive	0.02	-	0.37	-	0.97	-	0.58	-
Smother	**<0.01**	**4.16 (1.48-11.7)**	**<0.01**	**8.16 (2.94-22.7)**	0.73	-	**<0.01**	**2.39 (1.51-3.80)**
Tap	0.71	-	0.18	-	**<0.01**	**10.6 (2.36-47.4)**	**<0.01**	**4.49 (1.66-12.2)**
Fended	-	-	-	-	-	-	-	-
No (Reference)	-	-	-	-	-	-	-	-
Yes	0.92	-	0.32	-	0.51	-	0.36	-
Direction	**<0.01**	-	0.05	-	**<0.01**	-	**<0.01**	-
Front (Reference)	-	**1.00**	-	-	-	**1.00**	-	**1.00**
Side	**<0.01**	**0.41 (0.23-0.73)**	0.07	-	**<0.01**	**0.44 (0.32-0.61)**	**<0.01**	**0.53 (0.42-0.66)**
Back	**<0.01**	**0.24 (0.09-0.63)**	0.65	-	0.04	-	**<0.01**	**0.58 (0.39-0.87)**
FPOC	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
Head & Neck (Reference)	-	-	-	**1.00**	-	-	-	**1.00**
Shoulder & Armpit	0.99	-	0.06	-	1.00	-	**<0.01**	**0.05 (0.02-0.14)**
Torso	0.99	-	**<0.01**	**0.02 (0.01-0.07)**	1.00	-	**<0.01**	**0.01 (0-0.02)**
Upper Leg	0.99	-	**<0.01**	**0.02 (0.01-0.05)**	1.00	-	**<0.01**	**0.01 (0.02)**
Lower Leg	0.99	-	**<0.01**	**0.01 (0-0.05)**	1.00	-	**<0.01**	**0.01 (0-0.02)**
Speed - Tackler	0.19	-	0.91	-	**<0.01**	-	**<0.01**	-
Static (Reference)	-	-	-	-	-	**1.00**	-	-
In Motion	0.42	-	0.81	-	**<0.01**	**0.63 (0.47-0.84)**	0.02	-
High Speed	0.13	-	0.68	-	0.50	-	0.12	-
Speed - Ball Carrier	0.45	-	0.35	-	0.43	-	0.52	-
Static (Reference)	-	-	-	-	-	-	-	-
In Motion	0.96	-	0.49	-	0.24	-	0.32	-
High Speed	0.29	-	0.58	-	0.62	-	0.83	-
Body Position - Tackler	**<0.01**	-	0.06	-	0.12	-	0.04	-
Upright (Reference)	-	**1.00**	-	-	-	-	-	-
Bent	**<0.01**	**0.40 (0.24-0.67)**	0.10	-	0.29	-	0.05	-
Diving	0.03	-	0.02	-	0.37	-	0.67	-
Body Position - Ball Carrier	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
Upright (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
Bent	**<0.01**	**3.38 (1.62-7.08)**	**<0.01**	**2.33 (1.39-3.90)**	**<0.01**	**2.16 (1.52-3.05)**	**<0.01**	**2.42 (1.87-3.14)**
Diving	1.00	-	0.40	-	0.06	-	0.06	-

Note: Bold numbers represent statistical significance (p<0.01). ORs are only presented where there is statistical significance. Where the characteristic has a p-value of <0.01, the characteristic as a whole has a significant association to head contact. Results are presented to 2 decimal places, but OR >10 are presented to 1 decimal place.

6.3.5 Characteristics Associated With Head Contact: Primary Tackler

The number of tacklers had no effect on the likelihood of primary tackler head contact. Successful tackles were the most likely to result in primary tackler head contact (incomplete: OR=0.31; tackle break: OR=0.16; unsuccessful (missed): OR=0.03; p<0.01). Front tackles resulted in head contact more often than both tackles from the side (OR=0.32, p<0.01) and back (OR=0.35, p<0.01). Active tackles had a higher likelihood of primary tackler head contact when compared to passive (OR=0.57, p<0.01) and tap tackles (OR=0.23, p<0.01). Primary tacklers had the lowest likelihood of head contact when making contact with the ball carrier’s head & neck, but highest when making contact with their upper leg (OR=6.87, p<0.01) (shoulder & armpit: OR=3.72; torso: OR=3.68; lower leg=4.47; p<0.01). The likelihood of head contact was lowest when the tackler was in motion (OR=0.70, p<0.01). The primary tackler was less likely to have head contact when they were upright (bent: OR=4.42; diving: OR=3.15; p<0.01), but they were more likely to have contact when the ball carrier was upright (p<0.01) (bent: OR=0.39; diving: 0.15; p<0.01). Both U15 (OR-0.59, P<0.01) and U18 (OR=0.47, p<0.01) primary tacklers were less likely to have head contact than U13 primary tacklers (table 6.7).

Table 6.7: Odds ratios for tackle characteristics' association to primary tackler head contact.

	Under-13		Under-15		Under-18		Overall	
Characteristic (Ref)	**p**	**OR (95% CI)**	**p**	**OR (95% CI)**	**P**	**OR (95% CI)**	**p**	**OR (95% CI)**
Age	-	-	-	-	-	-	**<0.01**	-
U13 (Reference)	-	-	-	-	-	-	-	**1.00**
U15	-	-	-	-	-	-	**<0.01**	**0.59 (0.48-0.73)**
U18	-	-	-	-		-	**<0.01**	**0.47 (0.38-0.58)**
Quarter	0.38	-	0.48	-	0.19	-	0.32	-
Q1 (Reference)	-	-	-	-	-	-	-	-
Q2	0.95	-	0.49	-	0.21	-	0.55	-
Q3	0.12	-	0.13	-	0.12	-	0.27	-
Q4	0.39	-	0.69	-	0.04	-	0.07	-
Field - Vertical	0.13	-	0.10	-	0.44	-	0.67	-
A (Reference)	-	-	-	-	-	-	-	-
B	0.32	-	0.72	-	0.57	-	0.68	-
C	0.06	-	0.09	-	0.18	-	0.48	-
D	0.91	-	0.95	-	0.85	-	0.86	-
Try	0.72	-	0.79	-	-	-	0.76	-
Field - Horizontal	0.37	-	0.17	-	**<0.01**	-	0.02	-
1 (Reference)	-	-	-	-	-	-	-	**1.00**
2	0.16	-	0.03	-	0.86	-	0.06	-
3	0.64	-	0.39	-	0.02	-	0.01	-
4	0.16	-	0.16	-	0.02	-	**<0.01**	**1.46 (1.15-1.86)**
No of Tacklers	0.17	-	0.04	-	0.21	-	0.04	-
1 (Reference)	-	-	-	-	-	-	-	-
2	0.27	-	0.01	-	0.93	-	0.10	-
>2	0.13	-	0.59	-	0.08	-	0.04	-
Outcome	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
Success (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
Incomplete	**<0.01**	**0.34 (0.21-0.56)**	**<0.01**	**0.31 (0.19-0.51)**	**<0.01**	**0.19 (0.10-0.34)**	**<0.01**	**0.31 (0.23-0.41)**
Tackle Break	**<0.01**	**0.10 (0.06-0.17)**	**<0.01**	**0.21 (0.12-0.36)**	**<0.01**	**0.17 (0.11-0.29)**	**<0.01**	**0.16 (0.12-0.21)**
Unsuccessful (Missed)	**<0.01**	**0.02 (0.01-0.04)**	**<0.01**	**0.02 (0.01-0.05)**	**<0.01**	**0.04 (0.02-0.07)**	**<0.01**	**0.03 (0.02-0.04)**
Style	0.05	-	0.36	-	**<0.01**	-	**<0.01**	-
Active (Reference)	-	-	-	-	-	**1.00**	-	**1.00**
Passive	0.04	-	0.21	-	**<0.01**	**0.46 (0.31-0.69)**	**<0.01**	**0.57 (0.44-0.74)**
Smother	0.14	-	0.73	-	0.34	-	0.23	-
Tap	0.01	-	0.27	-	0.10	-	**<0.01**	**0.23 (0.09-0.58)**
Fended	-	-	-	-	-	-	-	-
No (Reference)	-	-	-	-	-	-	-	-
Yes	0.13	-	0.14	-	0.16	-	0.01	-
Direction	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
Front (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
Side	**<0.01**	**0.21 (0.09-0.50)**	**<0.01**	**0.33 (0.19-0.55)**	**<0.01**	**0.35 (0.24-0.51)**	**<0.01**	**0.32 (0.25-0.43)**
Back	0.12	-	**<0.01**	**0.32 (0.15-0.68)**	**<0.01**	**0.26 (0.15-0.46)**	**<0.01**	**0.35 (0.23-0.52)**
FPOC	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
Head & Neck (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
Shoulder & Armpit	**<0.01**	**5.72 (2.13-15.4)**	**<0.01**	**3.41 (1.52-7.64)**	**<0.01**	**3.15 (1.72-5.79)**	**<0.01**	**3.72 (2.42-5.70)**
Torso	**<0.01**	**4.68 (1.86-11.8)**	0.01	-	**<0.01**	**3.87 (2.16-6.95)**	**<0.01**	**3.68 (2.44-5.55)**
Upper Leg	**<0.01**	**8.04 (2.67-24.3)**	**<0.01**	**5.26 (2.08-13.3)**	**<0.01**	**7.00 (3.57-13.7)**	**<0.01**	**6.87 (4.26-11.1)**
Lower Leg	0.05	-	0.02	-	**<0.01**	**3.85 (1.63-9.10)**	**<0.01**	**4.47 (2.36-8.49)**
Speed - Tackler	0.51	-	0.08	-	**<0.01**	-	**<0.01**	-
Static (Reference)	-	-	-	-	-	**1.00**	-	**1.00**
In Motion	0.26	-	0.03	-	**<0.01**	**0.66 (0.50-0.86)**	**<0.01**	**0.70 (0.59-0.84)**
High Speed	0.99	-	0.85	-	0.83	-	0.89	-
Speed - Ball Carrier	0.14	-	0.54	-	0.22	-	0.04	-
Static (Reference)	-	-	-	-	-	-	-	-
In Motion	0.08	-	0.65	-	0.09	-	0.05	-
High Speed	0.79	-	0.28	-	0.40	-	0.96	-
Body Position - Tackler	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
Upright (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
Bent	**<0.01**	**6.60 (4.02-10.9)**	**<0.01**	**5.39 (3.51-8.29)**	**<0.01**	**3.58 (2.59-4.96)**	**<0.01**	**4.42 (3.54-5.52)**
Diving	**<0.01**	**2.89 (1.62-5.16)**	**<0.01**	**4.11 (2.32-7.29)**	**<0.01**	**2.90 (1.91-4.41)**	**<0.01**	**3.15 (2.37-4.18)**
Body Position - Ball Carrier	**<0.01**	-	**<0.01**	-	**<0.01**	-	**<0.01**	-
Upright (Reference)	-	**1.00**	-	**1.00**	-	**1.00**	-	**1.00**
Bent	**<0.01**	**0.22 (0.12-0.42)**	**<0.01**	**0.36 (0.22-0.57)**	**<0.01**	**0.44 (0.31-0.61)**	**<0.01**	**0.39 (0.30-0.49)**
Diving	1.00	-	0.02	-	**<0.01**	**0.22 (0.08-0.64)**	**<0.01**	**0.15 (0.07-0.33)**

Note: Bold numbers represent statistical significance ($p<0.01$). ORs are only presented where there is statistical significance. Where the characteristic has a p-value of <0.01, the characteristic as a whole has a significant association to head contact. Results are presented to 2 decimal places.

6.3.6 Characteristics Associated With Head Contact: Adjust Tackler

The number of tacklers had no effect on the likelihood of adjust tackler head contact. There were no significant differences between successful tackles, incomplete tackles or tackle breaks, but head contact was less likely when the tackle was unsuccessful (missed) (OR=0.03. $p<0.01$), when compared with a successful tackle. Overall, active tackles were more likely to result in head contact than passive tackles (OR=0.31, $p<0.01$). Adjust tacklers were less likely to have head contact when their FPOC on the ball carrier was the head & neck, rather than the torso (OR=2.57, $p<0.01$) or upper leg (OR=6.22, $p<0.01$). The upright body position was less likely to result in head contact for the adjust tackler than a bent body position (OR=3.96, $p<0.01$). When the ball carrier was upright, the adjust tackler had the highest likelihood of head contact (bent: OR=0.32; diving: OR=0.11; $p<0.01$). U18 (OR=0.31, $p<0.01$) adjust tacklers were less likely to have head contact than U13 adjust tacklers (table 6.8).

Table 6.8: Odds ratios for tackle characteristics' association to adjust tackler head contact.

	Under-13		Under-15		Under-18		Overall	
Characteristic (Ref)	**p**	**OR (95% CI)**	**p**	**OR (95% CI)**	**P**	**OR (95% CI)**	**p**	**OR (95% CI)**
Age	-	-	-	-	-	-	**<0.01**	-
U13 (Reference)	-	-	-	-	-	-	-	**1.00**
U15	-	-	-	-	-	-	0.06	-
U18	-	-	-	-	-	-	**<0.01**	**0.31 (0.20-0.50)**
Quarter	0.01	-	0.81	-	0.14	-	0.07	-
Q1 (Reference)	-	**1.00**	-	-	-	-	-	-
Q2	0.02	-	0.45	-	0.97	-	0.58	-
Q3	**<0.01**	**12.0 (2.42-59.6)**	0.91	-	0.35	-	0.06	-
Q4	0.02	-	0.89	-	0.04	-	0.02	-
Field - Vertical	0.14	-	0.72	-	0.47	-	0.65	-
A (Reference)	-	-	-	-	-	-	-	-
B	0.12	-	0.23	-	0.81	-	0.19	-
C	0.21	-	0.34	-	0.39	-	0.72	-
D	0.02	-	0.17	-	0.16	-	0.90	-
Try	-	-	1.00	-	-	-	1.00	-
Field - Horizontal	0.18	-	0.98	-	0.05	-	0.27	-
1 (Reference)	-	-	-	-	-	-	-	-
2	0.86	-	0.89	-	0.01	-	0.10	-
3	0.45	-	0.96	-	0.38	-	0.77	-
4	0.05	-	0.83	-	0.10	-	0.49	-
No of Tacklers	-	-	-	-	-	-	-	-
2 (Reference)	-	-	-	-	-	-	-	-
>2	0.95	-	0.39	-	0.12	-	0.10	-
Outcome	0.13	-	0.75	-	**<0.01**	-	**<0.01**	-
Success (Reference)	-	-	-	-	-	**1.00**	-	**1.00**
Incomplete	0.26	-	1.00	-	1.00	-	0.42	-
Tackle Break	0.03	-	0.78	-	0.72	-	0.24	-
Unsuccessful (Missed)	1.00	-	0.28	-	**<0.01**	**0.01 (0-0.16)**	**<0.01**	**0.03 (0-0.19)**
Style	0.85	-	0.47	-	0.06	-	0.01	-
Active (Reference)	-	-	-	-	-	-	-	**1.00**
Passive	1.00	-	0.17	-	0.02	-	**<0.01**	**0.31 (0.15-0.63)**
Smother	1.00	-	0.51	-	0.02	-	**<0.01**	**0.29 (0.12-0.73)**
Tap	-	-	1.00	-	0.26	-	0.29	-
Fended	-	-	-	-	-	-	-	-
No (Reference)	-	-	-	-	-	-	-	-
Yes	1.00	-	0.09	-	0.90	-	0.99	-
Direction	0.70	-	0.21	-	0.70	-	0.30	-
Front (Reference)	-	-	-	-	-	-	-	-
Side	0.42	-	0.85	-	0.94	-	0.72	-
Back	0.55	-	0.18	-	0.52	-	0.15	-
FPOC	0.77	-	0.10	-	0.22	-	**<0.01**	-
Head & Neck (Reference)	-	-	-	**1.00**	-	-	-	**1.00**
Shoulder & Armpit	0.31	-	0.13	-	0.60	-	0.03	-
Torso	0.20	-	0.04	-	0.26	-	**<0.01**	**2.57 (1.35-4.92)**
Upper Leg	0.56	-	**<0.01**	**91.2 (3.1-3067)**	0.05	-	**<0.01**	**6.22 (2.11-18.4)**
Lower Leg	1.00	-	0.22	-	0.10	-	0.04	-
Speed - Tackler	1.00	-	0.91	-	0.19	-	0.21	-
Static (Reference)	-	-	-	-	-	-	-	-
In Motion	0.93	-	0.72	-	0.32	-	0.39	-
High Speed	1.00	-	0.79	-	0.17	-	0.17	-
Speed - Ball Carrier	0.90	-	0.03	-	0.91	-	0.28	-
Static (Reference)	-	-	-	**1.00**	-	-	-	-
In Motion	0.65	-	0.43	-	0.76	-	0.87	-
High Speed	1.00	-	**<0.01**	**0.03 (0-0.43)**	0.67	-	0.13	-
Body Position - Tackler	0.19	-	0.02	-	**<0.01**	-	**<0.01**	-
Upright (Reference)	-	-	-	**1.00**	-	**1.00**	-	**1.00**
Bent	0.09	-	**<0.01**	**4.46 (1.53-13.0)**	**<0.01**	**4.15 (2.43-7.09)**	**<0.01**	**3.96 (2.61-6.01)**
Diving	0.73	-	0.78	-	0.03	-	0.04	-
Body Position - Ball Carrier	0.49	-	0.02	-	**<0.01**	-	**<0.01**	-
Upright (Reference)	-	-	-	**1.00**	-	**1.00**	-	**1.00**
Bent	0.35	-	**<0.01**	**0.22 (0.07-0.62)**	**<0.01**	**0.30 (0.18-0.51)**	**<0.01**	**0.32 (0.22-0.49)**
Diving	0.51	-	1.00	-	**<0.01**	**0.07 (0.01-0.31)**	**<0.01**	**0.11 (0.03-0.41)**

Note: Bold numbers represent statistical significance ($p<0.01$). ORs are only presented where there is statistical significance. Where the characteristic has a p-value of <0.01, the characteristic as a whole has a significant association to head contact. Results are presented to 2 decimal places, but OR >10 are presented to 1 decimal place.

6.4 Discussion

This study is the first to investigate the characteristics of youth rugby tackles and the association of these characteristics with head contact. It should be noted that the focus of this study is head contact, which may relate to the incidence of injury and concussion, but neither concussion, nor the magnitude of observed head impacts, are explored in this study. The key findings were: (1) The likelihood of ball carrier head contact was higher when there was more than one tackler; (2) tacklers had head contact more often than the ball carrier; (3) tackles from the front increased the likelihood of head contact for both the primary tackler and ball carrier; (4) tap tackles and tackles made at the height of the ball carrier's head & neck increased the likelihood of ball carrier head contact; (5) U13 tacklers had a higher likelihood of head contact than U15 and U18 tacklers.

6.4.1 Number of Tacklers

The number of players involved in the tackle was higher at older age groups (>1 tackler, U13: 11%; U15: 14%; U18: 24%), suggesting that the tackle situation gets more complex with age. As there is only ever one ball carrier but may be multiple tacklers, there are more opportunities for a tackler to get injured. Thus, the number of tackle events will be lower than the number of tackle exposures. This may contribute to the higher tackling injury incidence at U18 (10.7 injuries / 1000h), when compared to being tackled (8.0 injuries / 1000h) ($p=0.03$), in chapter four.

The likelihood of ball carrier head contact was significantly higher when there were two tacklers, when compared to one tackler, at all age groups (U13: OR=5.23; U15: OR=4.67; U18: OR=3.93; $p<0.01$). As the likelihood of head contact was lower for older players, this suggests that ball carriers may be better equipped to deal with a second tackler or that tacklers within older age groups are more able to conduct tackles which do not result in head contact. Whilst this is the case, the likelihood was dramatically higher when there were more than two tacklers at U18 (OR=15.1, $p<0.01$). No significant differences were found between one tackler and >2 tacklers at U13 and U15. This may be because the number of these situations was low (<1% of tackles) or because additional players lacked the skill to make meaningful contact when there were already two tacklers involved. What is important is that the number of tacklers does not have an effect on the likelihood of either primary or adjust tackler head contact. Thus, if the number of tacklers to was to be limited, the findings of this study suggest that ball carrier head contact may be reduced without impacting head contact when tackling.

6.4.2 Body Position, Direction & Speed

With the exception of U18 adjust tackles, the tackler consistently had head contact more often than the ball carrier, at least twice as often for the primary tackler. This is potentially due to body position. Overall, ball carriers are 2.4 times and tacklers are 4.0-4.4 times less likely to have head contact when upright, when compared to a bent body position. As ball carriers are upright more often (62-87%) than tacklers (33-57%), this may help to explain this.

In professional rugby, Tucker et al. (2017b) identified that front-on tackles were linked to an increased risk of requiring a Head Injury Assessment (HIA). Similarly, this study found that tackles from the front were linked to an increased likelihood of head contact for both the primary tackler and ball carrier. In the present study, most tackles came from the side, but the proportion of tackles from the front increased with age (U13: 10%; U15: 15%; U18: 20%). It was also found that primary tacklers who were in motion were 30% less likely to have head contact than when static. Whilst not investigated within this study, this may be because they were more likely to be upright and tackling from the side when in motion, which were both associated with a decreased likelihood of head contact. Future research should investigate the interactions between different characteristics.

Unlike the findings of Tucker et al. (2017b), who found that high speed tackles in professional rugby increased the risk of requiring an HIA, high speed tackles were not found to increase the likelihood of head contact. However, it is important to recognise that HIAs are not conducted within this setting and that tackles resulting in an HIA are likely to involve greater forces, due to heavier players and higher speeds, than the average head contact investigated within this study. It would be beneficial to understand how the forces experienced by the head of players at different ages and playing levels differ. Advances in technology in recent years has resulted in the introduction of instrumented mouthguards that house embedded sensors: accelerometers, gyroscopes and magnetometers. These can determine head linear and rotational accelerations, offering an opportunity to assess the number and magnitude of head accelerations experienced by players (Tierney et al., 2021). Whilst the majority of head injuries are caused by head impacts (Davidow et al., 2018), it is also possible for concussion to be caused without a direct impact to the head, as rotational forces can translate into inertial movement of the brain, resulting in the deformation of tissues and structures (Schweizer and Baker, 2022). Utilising this technology would allow researchers to capture instances where forces are experienced in the absence of head contact.

6.4.3 First Point of Contact & Style

In line with the findings of Burger et al. (2017), the likelihood of ball carrier head contact was greatest when they were tackled at the height of their head & neck. Conversely, tackling a ball carrier at the height of head & neck was least likely to result in head contact for the tackler. As with many characteristics, what would be beneficial for the ball carrier may not be for the tackler and vice versa. This was also the case for tap tackles. Whilst tap tackles resulted in a lower likelihood of head contact for primary tacklers ($OR=0.23$, $p<0.01$), they were 4.5 times more likely to result in head contact for the ball carrier overall and 10.6 times more likely at U18. This was largely due to head contact with the ground, accounting for 54% of all tap tackles resulting in head contact. Whilst tackling at the height of the head & neck and conducting tap tackles may be safer for the tackler, this shouldn't be accepted at the expense of the ball carrier's safety.

6.4.4 Age Groups

At U13, primary tacklers were significantly more likely to have head contact than U15 ($OR=0.59$) and U18 ($OR=0.47$) tacklers, despite having a lower proportion of successful and front-on tackles; both of which were associated with an increased likelihood of primary tackler head contact at all age groups. The higher likelihood of head contact may be due to the higher proportion of static tackles (U13: 59%; U15: 51%; U18: 46%) or due to poorer tackle technique, something which was not addressed within this study. Whilst this is the case, numerous studies have found that older age groups are at a greater risk of injury than younger age groups (chapter four) (Freitag et al., 2015b; Haseler et al., 2010; Viviers et al., 2018), highlighting that an increased likelihood of head contact does not necessarily equate to an increased risk of recorded injury.

6.4.5 Recommendations

Limiting the number of tacklers to one at U13 (>1 tacklers: 13%) and U15 (>1 tacklers: 14%) and to two at U18 (>2 tacklers: 2%) has the potential to reduce head contact for ball carriers. For the relevant tackles, this could reduce the odds of head contact by between 4.2 and 5.2 times per event for the two younger age groups. A similar reduction could be seen at U18, as tackles involving two tacklers are significantly less likely (OR=3.93, p<0.01) to result in head contact than those involving more than two (OR=15.1, p<0.01). Whilst tap tackles do not occur frequently (1-2% of tackles) they do pose a significant likelihood of head contact for the ball carrier, so it is also recommended that the banning of tap tackles is considered at all age groups. Whilst there were no significant differences between active tackles and tap tackles at U13 and U15, tap tackles were 10.6 times more likely to result in ball carrier head contact at U18 and 4.5 times overall.

Players in the under-12 to under-14 age groups are not permitted to tackle above the armpit, however, at U15 and U18, players are permitted to tackle at the height of the shoulder. For the 2021/22 season, England Rugby extended the under-14 tackle laws so that all age groups, up to under-18, must tackle below the line of the armpit (England Rugby, 2021b). The findings of this study suggest that this will likely reduce the number of head & neck tackles and likelihood of ball carrier head contact at U15 and U18. A reduction is tackled height was also trialled in the English Championship (Stokes et al., 2021b); although the intervention did alter the characteristics of the tackle, reducing the amount that tacklers made contact with the ball carrier’s head and neck by 30%, it did not significantly reduce the rate of concussion. It is possible that tackling at a lower height could increase the likelihood of neck flexion which, during impact on the central and posterior parts of the head, can increase cervical spine internal loading and, therefore, injury risk (Silvestros, Preatoni, Gill and Cazzola, 2022). However, 83% of known tackle heights within this study were below the height of the armpit, yet only 3% of injuries were to the neck (APPENDIX N).

As the quantity of tackles making initial contact with the head & neck is higher at older age groups, it is likely that players are not learning lessons when they are younger. There were limited penalties and cards, despite the quantity of tackles making contact with the ball carrier’s head & neck. Although, not all tackles making contact at the height of head &

neck would be considered illegal. For instance, a ball carrier may be bent at the waist when they make contact, which would mean that the tackler's first point of contact would be the head & neck, despite not being a high tackle. Future studies should seek to identify illegal high tackles in order to determine the extent of the issue. Regardless, it is important that referees rigidly enforce the pre-existing law of not tackling at head & neck height, as tackles with a FPOC of below the head & neck were found to have a lower likelihood of ball carrier head contact (shoulder & armpit: OR=0.05; torso: OR=0.01; upper leg: OR=0.01; lower leg: OR=0.01; $p<0.01$).

What is important is that a focus is placed on teaching safe and effective tackle technique at all age groups. Specifically, players should be taught how to safely conduct different types of tackle in a variety of settings. They should also be encouraged to get into positions where they can tackle in motion and from the side. When tacklers are in motion, rather than static, they are 30% less likely to have head contact. Tackling from the side, rather than the front, is 47% less likely to result in ball carrier head contact and could reduce the likelihood of primary tackler head contact by 65-68%. Increasing the size of the pitch at U13, from 90x60 metres to a full-size pitch (100x70 metres), would give players more space (width) to move, which may increase the proportion of in motion, side-on tackles. Future studies should investigate whether this would also be beneficial at younger age groups; specifically, between under-9 and under-12 where the game is played with contact and on a pitch smaller than at U13.

Within youth rugby, Burger et al. (2016) discussed the importance of tackle technique, finding an association between higher technical scores and a non-injury outcome. Interestingly, the technical scores were lower for side-on tackles than front-on tackles, for both the tackler and ball carrier, highlighting the need to improve side-on tackle training. Another study by Burger et al. (2017) found that the risk of injury increased for both the ball carrier and tackler in the second half of the match. We found no evidence that the likelihood of head contact increased later in the game, suggesting that the focus should be on additional technical training rather than additional conditioning sessions.

6.4.6 Limitations

The quality of the footage and single camera angle meant that 6% of all tackle characteristics were unknown. Most importantly, over 20% of all head contact data was missing (i.e., it could not be confirmed whether there was or was not head contact) and these were not able to be included within the statistical models. It is possible that the characteristics which were unknown were those during a particular tackle situation or on a particular area of the pitch. For instance, it may have been more challenging to identify head contact when the tackle occurred in a congested area or when there was more than one tackler. Future studies should consider a second camera angle and / or a camera worn by the referee.

It is important to note that head contact does not always result in injury or concussion and that it was not possible to characterise the magnitudes of the head impacts discussed within this study. Future studies should consider the use of instrumented mouthguards, a tool which has been previously been utilised to improve the understanding of impact kinematics in university-level rugby (Williams et al., 2021). This would help to identify tackle situations which are responsible for the highest magnitude head impacts. It would also help to identify instances where the head experiences forces, despite there not being head contact; something which was not captured within this study.

The purpose of this research was to better understand the characteristics of schoolboy rugby tackles at various age groups in England and their association with head contact. The interactions between tackle characteristics and the quality of tackle technique were not investigated and so further research should also investigate the impact of these factors on head contact within this setting.

6.5 Conclusion

This study is the first to investigate the characteristics of youth rugby tackles and their association with head contact. Tacklers had head contact more often than ball carriers and the likelihood of head contact was higher at U13 than at U15 and U18 for the tackler, but there were no age-related differences for the ball carrier. Teaching safe and effective tackle technique must be a priority at all age groups and players should be encouraged to get into positions where they can tackle in motion and from the side. The findings of this study suggest that tackles to the head & neck are not being penalised, which may contribute to the increased number of head & neck tackles at older age groups, and provides evidence in support of England Rugby's decision to trial a reduction in tackle height to below the armpit across age-grade rugby. It also provides evidence which suggests that banning the tap tackle and limiting the number of tacklers to one at U13 and U15 and to two at U18 may reduce the likelihood of head contact.

CHAPTER SEVEN

GENERAL DISCUSSION

7.1 Introduction

This thesis aimed to investigate the nature of injuries within English schoolboy rugby and to explore the events which cause them. After setting the scene in chapter one and providing a contextual background in chapter two, the general methodologies used within this thesis were outlined within chapter three. Chapter four was the first study to describe and compare the epidemiology of injuries across various age groups within this setting and highlighted numerous areas of interest and differences between age groups. Chapter five utilised the data from chapter four and added context to it through the use of match analysis. Initially, this chapter described the characteristics of matches at different age groups, before identifying the risk that each contact event poses to players of different ages. Finally, the tackle, which was shown to be a key event within chapters four and five, was investigated. After the characteristics of the tackle at different age groups were described, the association of these characteristics with head contact was investigated. This body of work provides a useful reference regarding the game at different age groups in schoolboy rugby, has laid the foundation for future injury prevention strategies and has made numerous practical recommendations. This chapter summarises the main findings of this thesis by re-visiting the original research questions. It then discusses the practical implications of this work and identifies the directions that future work could take.

7.2 Addressing the Research Questions

Despite the concerns surrounding the game of rugby being played within a youth population and the evidence that the incidence of injury increases with age, very little was known about injuries across different age groups within English schoolboy rugby. This led to the development of the first research question. It was not clear how the game at each age group differed or whether the increase in injury incidence with age was because events were becoming more numerous or had a greater likelihood of resulting in injury. This resulted in the second and third research questions. Despite the fact that the tackle has been found to be both the most common event and the one responsible for the most injuries and concussions, very little was known about the characteristics of this event at different age groups and how these characteristics affected the likelihood of head contact. This resulted in the development of research questions four and five.

(1) What is the incidence, severity and burden of injuries within English schoolboy rugby and does this differ between age groups?

The incidence and burden of injury was higher at U18 (incidence: 34.6 injuries / 100h; burden: 941 days / 1000h) than at U13 (incidence: 20.7 injuries / 100h; burden: 477 days / 1000h) and U15 (incidence: 24.6 injuries / 100h; burden: 602 days / 1000h), but there were no significant differences between the two younger age groups.

The increase in burden with age was largely due to an increase in the incidence of injuries, rather than an increase in the severity of them.

Tackles caused the most injuries at all age groups (48-62%) and were primarily responsible for the higher incidence and burden seen in the U18 age group.

Concussion was the most common type of injury at all age groups (25-27%), but there were no significant differences in the incidence of concussions between age groups.

(2) What is the frequency of match events in schoolboy rugby matches and does this differ between age groups?

The tackle was the most common contact event at all age groups (U13: 212; U15: 187; U18: 230 per match), however there were significantly more successful, break and incomplete tackles at U18 (197) than at U13 (169) and U15 (155).

At U13, there was a higher number of clean breaks (U13: 14; U15: 10; U18: 8), passes (U13: 219; U15: 175; U18: 206) and tries (U13: 10; U15: 8; U18: 6) than at U15 and U18.

The number of U13 tackles could be reduced by increasing pitch size or decreasing ball in play time, which is higher (55%) than at U15 (43%) and U18 (44%).

(3) What is the propensity for injury for different contact events and does this differ between age groups?

Accidental collisions had the highest propensity for injury (U13: 25.2 injuries / 1000 events; U15: 39.9 injuries / 1000 events; U18: 24.9 injuries / 1000 events) and were responsible for the most days lost / 1000 events (U13: 437 days / 1000 events; U15: 1065 days / 1000 events; U18: 847 days / 1000 events) at all age groups, but there were no significant differences between age groups.

The U18 tackle had a higher propensity for injury (2.9 injuries / 1000 events) and was responsible for more days lost / 1000 events (97 days / 1000 events) than both U13 (propensity: 1.0 injury / 1000 events; days lost: 30 days / 1000 events) and U15 tackles (propensity: 1.7 injuries / 1000 events; days lost: 56 days / 1000 events).

The focus should be on enforcing tackle law and teaching proper technique at all age groups. Long-term, this may reduce the tackle's propensity for injury at U18.

(4) What are the characteristics of the tackle at different age groups?

At all age groups, most tackles were passive (59-68%), came from the side (67-79%) and made first contact with the torso (43-59%). The ball carrier was most commonly either in motion or at high speed (85-87%), with an upright body position (74-87%).

The number of additional tacklers (>1) (U13: 11%; U15: 14%; U18: 24%) and proportion of tackles coming from the front (U13: 10%; U15: 15%; U18: 20%), with a bent body position (U13: 27%; U15: 32%; U18: 39%) and either in motion or at high speed (U13: 38%; U15: 46%; U18: 50%) increased with age.

Adjust tacklers were more successful (93-95%) than primary tacklers (56-75%). They were also static (adjust: 57-86%; primary: 46-59%), came from the front (adjust: 19-25%; primary: 10-20%) and made contact with the head and neck (adjust: 4-9%; primary: 2-4%) more often than primary tackles.

(5) Which characteristics of the tackle are associated with increased head contact and does this differ between age groups?

With the exception of U18 adjust tacklers, the ball carrier (U13: 14%; U15: 17%; U18: 22%) had head contact less often than both primary (U13: 47%; U15: 43%; U18: 43%) and adjust (U13: 55%; U15: 50%; U18: 35%) tacklers.

The likelihood of ball carrier head contact was higher when there was more than one tackler (2 tacklers: OR=4.2; >2 tacklers: OR=8.1).

Tap tackles (OR=4.49) and tackles made at the height of the head & neck (shoulder & armpit: OR=0.05; torso: OR=0.01; upper leg: OR=0.01; lower leg: OR=0.01) increased the likelihood of ball carrier head contact.

Tackles from the front increased the likelihood of head contact for both the primary tackler (side: OR=0.53) and ball carrier (side: OR=0.32; back: OR=0.35).

U13 primary tacklers were significantly more likely to have head contact than U15 (OR=0.59) and U18 (OR=0.47) primary tacklers.

7.3 Original Contribution to the Knowledge

This thesis has made numerous original and meaningful contributions to the knowledge; these are outlined below:

- Investigating the differences between age groups, in the context of both injuries and match events, in English schoolboy rugby union.

- Providing a reference for the number and type of both contact and non-contact events occurring within rugby matches.

- Highlighting the contact events with the highest propensity to cause injury.

- Describing the characteristics of the tackle at different age groups.

- Identifying characteristics of the tackle which are associated with an increased likelihood of head contact.

- Laying the foundation for the creation of age-specific injury prevention strategies by recommending focus areas for training, considerations for law changes and directions for future research in this area.

7.4 Practical Implications & Potential Impact

The aim of this thesis was to investigate the epidemiology of injuries and match events to inform strategies to reduce the risk of injury within schoolboy rugby. The findings captured within this body of work are likely to be useful and relevant for numerous stakeholders, including coaches, healthcare professionals and policy makers. For coaches, this thesis makes several training-related suggestions and provides a reference which can be used to develop their understanding of the game, and the risks associated with it, at different age groups. For healthcare professionals and policy makers, the findings of this thesis address the first two phases of "the sequence of prevention" (van Mechelen et al., 1992), providing a foundation for future age-specific injury prevention strategies. It also makes numerous recommendations for law changes which are likely to reduce the risk of injury in this setting.

The first study in this thesis, chapter four, shaped the rest of the thesis by identifying key focus areas. It confirmed that, in line with the literature (Freitag et al., 2015b; Haseler et al., 2010; Viviers et al., 2018), injury incidence does increase with age. As the incidence and burden of U18 injuries were higher than the two younger age groups, this highlighted the U18 age group as the age group of greatest concern, despite concerns about younger players (Carter, 2015; Pollock et al., 2017). As there were no significant differences in the severity of injuries at different age groups, this suggests that it is a higher injury incidence which is largely responsible for the higher injury burden. What is clear is that the tackle is primarily responsible for the higher rate of injury at U18. Although concussions were found to be the most common type of injury at all age groups, they were largely caused by the tackle, so addressing issues with the tackle may, in turn, reduce the both the incidence of injury and concussion.

The second study in this thesis, chapter five, built on the findings of chapter four. This was the first time that match events had been described and propensity for injury had been calculated in a youth setting. Whilst occurring infrequently and resulting in less injuries than the tackle, the accidental collision was the highest risk event at all age groups, so it is important that coaches and players are educated on the risks associated with it and that players are encouraged to be situationally aware. This could be achieved by incorporating more complex situations into training, such as having defenders move from difficult-to-see areas of the pitch, which would help to develop visual search behaviours, anticipation and decision making (Huffman, Crundall, Smith and Mackenzie, 2021).

Not only was the tackle found to be responsible for the most injuries within chapter four, but it was also found to be the most common event and the one with the second highest propensity at all age groups in chapter five, suggesting that it should be the focus on future interventions. It was found that tackles at U18 were both more numerous and had a higher propensity for injury, resulting in a higher injury incidence and burden than the two younger age groups. Given that better tackle technique has been associated with non-injury outcomes (Meintjes et al., 2021; Burger et al., 2016), banning the tackle at U13, and thus removing opportunities to practice safe and effective tackle technique, may not be beneficial. Whilst it could be argued that young players could practice tackling during training and not tackle during matches, it is important that they are given opportunities to learn how to tackle safely during gameplay, whilst their relative risk of injury is low. If young players do not gain experience and are introduced to full contact games when the risk is higher, this may increase tackle-related injuries at older age groups.

In order to reduce the tackle-related injury risk, this thesis made two key suggestions. Firstly, there should be an increased focus on teaching tackle technique at all age groups, as better technique has consistently been shown to reduce the risk of injury (Burger et al., 2016; Burger et al., 2017; Hendricks et al., 2016). Specifically, players should be taught how to safely conduct different types of tackle in a variety of settings and be encouraged to get into positions where they can tackle in motion and from the side. World Rugby has recently released Tackle Ready (World Rugby, 2021), a programme targeting both coaches and players and seeking to improve their technical understanding of the tackle. This programme is split into five phases: tracking, preparation, connection, acceleration and finishing. Given that this programme develops both static and dynamic tackle technique through the progressive practice of specific drills and activities, it is possible that using this programme may address this first recommendation. During the first phase, tracking, players are taught how to get to the ball carrier effectively by coaching them through "vision, decision, action". It is possible that this increased focus on vision and decision making may also improve situational awareness and reduce the occurrence, and thus incidence, of accidental collisions.

Secondly, match officials must ensure that they enforce proper tackle technique by penalising dangerous play. Across the 60 matches analysed within chapter five, only three yellow cards were identified. Whilst it was not clear how many of the 2,002 fouls were for dangerous play, it is possible that dangerous play is not being sanctioned. This may be because referees are trying to give young players as much time on the pitch as possible. Whilst this is beneficial for player development, this also means that players may not be learning important lessons about safe gameplay. It is possible that the introduction of a "green card", which could see the removal of a player for two minutes and the awarding of a yellow card for a second offence, may be beneficial. This would allow referees to address dangerous gameplay when they do not feel a yellow card is warranted, whilst limiting the removal of players. This may develop safer behaviours and, in time, reduce injury incidence at U18.

In chapter six, U13 players were found to have the greatest likelihood of head contact during a tackle, even if their risk of injury per 1000 tackles is lower than at U18. Whilst the number of tackles should be reduced at all age groups, this thesis did identify ways in which this might be achieved at U13. One option would be to give players more space to move, by allowing them to play on a full size 100x70 metre pitch (rather than a 90x60 metre pitch). Increasing the width of the pitch may also reduce the proportion of static, front-on tackles, which were found to have a higher likelihood of head contact. Whilst this may increase the number of high speed tackles, which pose a similar risk to static tackles, it is likely that it is the number of in motion tackles which would increase most dramatically. This is because the proportion of high speed tackles is not that much greater at U15 and U18, both of which play on a full size pitch. The number of tackles at U13 could also be reduced by decreasing the proportion of the match where the ball is in play, as it is higher than at U15 and U18. It is likely that this is because they do not conduct lineouts or kick at goal, which may be to allow young players to focus on other aspects of the game. As the clock is not permitted to stop within youth matches, if lineouts and kicking at goal were introduced, this would likely reduce the ball in play time, subsequently reducing the number of tackles. However, this could have a negative effect on ball handling skills, as there would be less opportunity to practice, so the effects of any law changes should be investigated through the use of match analysis.

Whilst it is not currently clear how the number of tackles could be reduced, particularly at U15 and U18, there are numerous law changes which could be made to reduce the likelihood of head contact. Firstly, the number of tacklers should be limited to one at U13 and U15 and two at U18, affecting 11% of U13, 14% of U15 and 2% of U18 tackles (chapter six). Not only would this likely reduce the likelihood of ball carrier contact, but may force players to tackle with better technique, as the number of players which could assist with the tackle would be limited. This thesis also provides evidence to support the reduction in tackle height at U15 and U18, from the shoulder to the armpit, being trialled by England Rugby (2021b); the findings of this thesis suggest that this may reduce the likelihood of ball carrier head contact. Finally, banning the tap tackle should be considered at all age groups, as this type of tackle is 4.5 times more likely to result in head contact overall and 10.6 times more likely to result in head contact at U18, compared to active tackles. It is likely that this would not have a large effect on gameplay, as tap tackles account for less than 2% of known tackles. However, it is possible that this may increase the number of tries being scored, given that tap tackles are usually conducted when a player is travelling at high speed towards the try line.

As suggested by Burger et al. (2020), it is likely a combination of education, law change and tackle technique training that will have the greatest impact on injury risk. The game of rugby and aetiology of injury is complex, so there is likely no single, simple solution. By educating coaches on the risks of accidental collisions and need for tackle technique training, giving referees additional tools to use to penalise dangerous actions, altering pitch size and law to encourage evasion over contact and banning the characteristics of the tackle which are of greatest concern, this may reduce the incidence of tackle-related injuries over time, subsequently reducing the incidence of injury and concussion.

7.5 Future Directions

This section seeks to identify areas for future research, which would build on the findings of this thesis, and covers three key topics: injury surveillance, penalisation and the tackle.

It is recommended that the scale of schools' injury surveillance be increased to include female rugby players, players from other age groups and the seven-a-side game. Despite the fact that there is evidence that there are differences between the male and female games (Barden et al., 2021; West et al., 2021), there is currently no data available for the English youth female game. Similarly, there is also no data available for the male under-14 and under-16 games, both of which have slightly different laws to the age groups investigated within this thesis (England Rugby, 2021a). Whilst there are several themes which are consistent across age groups, it appears that there are different strategies to overcome them at each age group. As the incidence of injury in rugby sevens has been shown to be higher than the fifteen-a-side game (Cruz-Ferreira et al., 2017; Lopez et al., 2020), but has not been investigated in an English schoolboy setting, this is also an important area for investigation. Increasing the number of schools involved within the Youth Rugby Injury Surveillance project may also allow for an investigation of injury rates at different types of school. State-funded schools are likely to have less money, fewer resources and less support staff than independently-funded schools, but it is not clear if this affects the risk of injury. Whilst data from both independently-funded and state-funded schools was collected, it was not possible to investigate differences between them due to the small number of state schools who provided data.

It would also be beneficial to investigate training injury risk as, although the incidence of training injuries has been found to be lower than match injuries, players generally spend more time training than playing in matches (Williams et al., 2013; Palmer-Green et al., 2013; Palmer-Green et al., 2015; Viviers et al., 2018). This is of particular interest in this setting given that Palmer-Green et al. (2015) found the incidence of schoolboy rugby training injuries (2.1 injuries / 1000h) to be higher than that of academies (1.4 injuries / 1000h); although this just failed to reach the threshold for significance. It is possible that this is because they train less often (72 hours per season), when compared to academy players (190 hours per season), resulting in players who are less prepared for the demands of the sessions. It may also mean that schoolboy players may need to incorporate more contact training into their sessions or to work at a greater intensity, due to the limited available time. Context could be added with the collection of player-level data, such as previous injury and physical characteristics, to help develop the understanding of risk factors for different age groups and to further inform appropriate injury prevention strategies.

Throughout, this thesis has highlighted possible issues surrounding penalisation and the use of cards. This was not investigated as the quality of match footage and fact that the referee could not be heard meant that distinguishing between penalties and free kicks, seeing hand signals and understanding decisions was not possible. Future research should consider using a second camera angle (and / or a referee camera) and a microphone for the referee. Research investigating referee decision making and penalisation has been carried out at various levels of the sport, but an investigation such as that carried out in South Africa by Brown et al. (2018) would be beneficial in English schoolboy rugby. By understanding both the quantity of illegal tackles taking place and whether they are being sanctioned would help develop an understanding of whether a “green card” might work in this setting.

This thesis has also consistently highlighted the importance of tackle technique training; however, tackle technique was not investigated. A study similar to that conducted by Burger et al. (2016) would confirm whether poor technique is associated with an increased risk of injury within this setting. It may also identify age-specific issues surrounding technique, which could inform new, and improve existing, tackle technique training strategies. Whilst chapter six did not suggest that a player’s likelihood of head contact increases later in the game, understanding whether the quality of tackle technique decreases as the game progresses would provide insight into whether the current age-grade time limits are appropriate or whether there is a conditioning issue that was not identified within this body of work. Further context could be given to the tackle, in relation to head contact, if the magnitude of head impacts could be understood. Given that U13 players have the greatest likelihood head contact but lowest risk of injury, this suggests that head contact is not directly related to injury. Investigating the magnitude of head impacts at different age groups and during different contact events, using instrumented mouthguards, would allow stakeholders to better understand the risks posed by different match events for players of different ages (Tierney et al., 2021). Given that equipment such as this is expensive, which could limit the number of participants, another option is to utilise match analysis to identify significant head contacts.

There are also three trials of tackle-related law changes which should be investigated or considered. Firstly, it is important that England Rugby’s tackle height reduction trial for the U15 to U18 age groups be evaluated, comparing epidemiological data from the 2021/22 season to previous seasons to determine whether injury risk has been reduced. Whilst this thesis supported their decision to trial a reduction in tackle height to the armpit, a similar trial in the English Championship did not find that this reduced the incidence of concussion or injuries (Stokes et al., 2021b). However, it did mean that tackers made contact with the ball carrier’s head & neck 30% less often. An analysis identical to that used within chapter six would also help policy makers to understand the impact that this trial has had on head contact. Secondly, it is important that strategies to reduce the number of tackles occurring during match play be identified at all age groups, given that tackles are the most numerous contact event and that the propensity of tackle injuries was found to be so high. A trial investigating whether increasing pitch size and / or reducing ball in play time at U13 reduces both the number of tackles and tackle-related injuries should be considered. Future research should seek to identify strategies which are likely to achieve the same aims at U15 and U18. Finally, a trial where the tap tackle is banned and the number of tacklers are limited to one at U13 and U15 and to two at U18 should be considered, with a view to determining whether this is an effective method to reduce both the likelihood of head contact and the incidence of tackle-related injuries.

7.6 Thesis Conclusions

During this thesis, five research questions were addressed, representing the first time that English schoolboy rugby injuries have been investigated across various age groups and in the context of game events. The U18 age group is at the greatest risk of injury, primarily due to the tackle, which is both more common and poses a higher risk than at younger age groups. The event which is of the greatest risk to players is the accidental collision; it is important that players are educated on the risks of this event and that players' situational awareness is developed. The most common type of injury at all age groups was concussion, but concussion incidence may be reduced by addressing issues with the tackle. At U13, increasing pitch size and reducing ball in play time could reduce the number of tackles, however strategies to reduce the number of tackles should be investigated for the U15 and U18 age groups. At all age groups, safe and effective tackle technique should be taught for different tackle types and in a variety of settings. Players should also be encouraged to look for opportunities to tackle from the side and in motion, as these characteristics were associated with a lower likelihood of head contact. This findings of this thesis provide evidence in support of England Rugby's decision to trial a reduction in tackle height to below the armpit across age-grade rugby. It also provides evidence which suggests that banning the tap tackle and limiting the number of tacklers to one at U13 and U15 and to two at U18 may reduce the likelihood of head contact. In conclusion, this thesis has provided a useful reference for key stakeholders, recommended future directions for research and laid the foundation for age-specific injury prevention strategies.

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APPENDICES

APPENDIX A - POSTGRADUATE DATA MANAGEMENT PLAN

Postgraduate Data Management Plan

1 Overview

1.1 Project name	Youth Rugby Injury Surveillance Project
1.2 Plan author	Matt Hancock (Student), Prof Keith Stokes (Supervisor), Dr Simon Roberts (Supervisor)

1.3 Project description

This study will compare the incidence, severity, mechanism and type of injuries across different age groups and types of schools, for the fifteen-a-side and seven-a-side game. Matches will also be analysed in order to better understand the number of events within the game for different populations, before analysing the tackle to look for characteristics which would increase likelihood of injury or of a successful tackle.

2 Compliance

2.1 With what legislative, contractual and policy requirements must the project comply?

The project will comply with the University of Bath Research data policy (*http://www.bath.ac.uk/research/data/policy/research-data-policy.html*).

Prior to commencing the study, all participants will be provided with an information sheet detailing the study overview, what will be required from them and what benefits/risks the study may have. Once they have read through this, and had the opportunity to ask any questions, they are required to sign an informed consent form. Participants under the age of 18 years old will be provided with an assent form, whilst their parents/guardians will be required to sign an informed consent form for their child's inclusion in the study.

Much of the data collected will be completely anonymous and thus is not classed as personal or sensitive data and does not fall under the General Data Protection Regulation (http://www.bath.ac.uk/data-protection/GDPR/index.html). However, there are aspects of the study which do require an individual's personal data and is thus included under the General Data Protection Regulation and the University of Bath's Data Protection Policy (http://www.bath.ac.uk/data-protection/data-protection-act/data-protection-policy/index.html).

All data collected will be stored on the University of Bath 'X-drive' in a restricted folder (Location: Location: X-Drive> Health> ResearchProjects> KStokes> RE-FH1191) which is only accessible by the members of the YRISP research team.

All members of the research team will adhere to the University of Bath's IT security policy (http://www.bath.ac.uk/corporate-information/university-of-bath-electronic-information-systems-security-policy). As per the policy, the most senior member of the team, Prof Keith Stokes, is required to be the data steward.

In accordance with the University of Bath policy all data will kept for a minimum of 10 years, after which datasets may be kept but any personal data will be removed so that individuals are no longer identifiable.

This research project is funded by the Rugby Football Union (RFU). Data collected will belong to the team or individual, until it is anonymised by the research team at the University of Bath. After which, this data will be owned by RFU, but the University of Bath will be analysing and storing this data.

2.2 What data will the project require?

Much of the data will be stored as an .xlsx file given this is the format that we will receive the injury and exposure data from participants as we have provided them with an excel document for them to populate.

We appreciate some participants may prefer to provide information through a paper format. This data will be then be transferred and stored onto a .xlsx file as per above. Paper documents that are collected will be kept in a data storage facility in 1.West. It is estimated that these paper documents will fill no more than 1 filing cabinet.

Each match that is filmed will be expected to take up 2.5GB. As we are expecting to record 180 matches (60 / age group), we estimate that this will take up no more than 450GB for the 2018/19 season.

It is estimated that the volume of data will fall within the 500GB – 1TB range and it is not anticipated that the project will require authorization to exceed this volume of data.

2.3 How will these data be gathered?

Injury and exposure data will be collected by a pre-determined individual at the school who will record the information on a pre-made spreadsheet or paper recording forms, which will then be provided to the research team. All of this data is anonymous.

There will be increased amounts of data received at the beginning (e.g. consent forms) and end (e.g. finalisation of injury and exposure data) of the season. However, we intent to correspond with schools on a monthly basis so that data is fed through regularly and we can address any issues throughout the year if needed.

An external company is being used to collect match footage. Filming will be organised directly with the school and a cameraman/camerawoman will be sent along to matches to film. These will then be sent to Bath University securely using https://files.bath.ac.uk/. These files will be stored as .mov or .mp4 files, ready to analysed using NAC Sport match analysis software.

2.4 What original software, if any, will the project create?

We do not intend to develop any software specific to this study.

3 Working with data

3.1 Where and how will the data be stored?

The University of Bath 'X-drive' will be the primary location of data storage given that it is secure, is backed up and mirrored. The folder where the data is stored (X-Drive> Health> ResearchProjects> KStokes> RE-FH1191) is restricted and only accessible by the members of the research team involved with this study. A backup of raw data, relating to each individual research members involvement with the project, will be stored on their 'E-drive' of their desktop computer. Desktop computers require a University of Bath sign-in and unique password, whilst all computers are in individual or Rugby Science offices which are only accessible by the group and locked when unattended. A third back up of raw data will be stored on individuals own personal 'H-drive'.

The electronic data provided to the research team by the school will be done behind the University of Bath firewall through https://files.bath.ac.uk/. Only the research team and designated school staff member will have access to the files, though a password will be required. The methods for sharing and receiving this information can be seen at the end of this section. It should be noted that files sharing ability will expire after 2 weeks and thus all data needs to be extracted within this time frame. There is also a 2GB limit per file.

Schools who are using paper copies may collect these and send any anonymised data into the research team at Bath through a postal service. Any personal data must be handed over in person and thus it is acceptable for the school to collect their data in a ring binder throughout the course of the season. Data from these paper documents will be transferred to an electronic document, and stored as above, before the physical copy is then stored in a secure storage facility in 1.West. Copies of paper documents will be made and stored in a locked filing cabinet in the Rugby Science offices in Wessex House.

- Sending Data
    1. Open https://files.bath.ac.uk/
    2. Log in using university password and log in
    3. Beside the symbol near the top of the screen, click the symbol
    4. Select folder and give folder a name
    5. New folder will now appear next to H-Drive and X-Drive in home screen
    6. Open folder and drag and drop file you wish to send into it.
    7. Returning to the "Home" screen, click the share symbol to the right of the new folder, this will open a new section of screen
    8. Click the "share link" box and type a password (remember to send password to recipient in separate email/text)

9. A new link will appear under the "share link" box.
10. Copy this into your email to recipient and they can now open and receive the file when they enter the password.

- Receiving Data
  1. Repeat steps 1-8 as above (excluding 6)
  2. To receive data, check the "allow editing" box
  3. Send link to recipient
  4. Recipient can now drag and drop their data into the folder which will then appear in the new folder on your home page.
  5. Move this data asap once transferred to avoid the folder being removed.

3.2 How will access be controlled?

All access will be restricted through different means depending on their storage location. As previously mentioned, all data received will be stored on the 'X-Drive' in a folder which is only accessible by the research team. Electronic data which is provided to us from participating schools will be stored in an encrypted file, specific to that school, which is password protected and only accessible to the pre-determined member of school staff and the research team.

Paper copies will be stored either in a restricted storage facility, 1.West, with copies in a locked filing cabinet only accessible to the research team in Wessex House.

3.3 How will the data be organised?

Given that there are several members of the research team, a specific structure on file storage will be adopted to ensure that it is clear what folder and file relates to which area of the study, as well as making it easy to track the version of edit. Read me file directories and clear naming conventions should improve transition between studies and ease in which data can be located.

All new files should follow the following naming convention detailed below.

- Data files
  1. Typeofdata_team/subject_Datescovered_raw/clean
     - E.g. injury_Bath_Nov18toApril19_raw
     - E.g. activate_Bath_Sept18toDec18_raw

- Picture Files
  1. Picturedescription_photographer_year
     - Activateexercises_CBarden_2018

- Journal Articles
  1. Author_articlename_year
     - E.g. Gabbett_Thetraining-injurypreventionparadox_2016

- Word documents

1. Drafts- Documenttitle_Author_Datemodified_DraftNumber
    - E.g. ActivateAdherence_CBarden_22Jul2019_V1

2. Final copies- Documenttitle_Author_Datemodified_DraftNumber
    - E.g. ActivateAdherence_CBarden_22Jul2019_Final

- Presentations
    1. Presentationtitle_Author_Dateused
        - E.g. ActivateWorkshop_CBarden_19Jan2019

3.4 What documentation will accompany the data?

A master spreadsheet with a list of schools will be used to organise the data collection. This details which schools are taking part, contact details, any correspondence, what information that they have received, data they have sent and any school-specific requirements.

Within each file, a "Readme file" will be included, which will explain the documents that are enclosed.

4 Archiving data

4.1 Which data should be retained long-term? Which will be deleted at the end of the project?

It is important to retain all data that may support publication whilst keeping it to ensure that findings could be reproduced and validated should they be needed to.

Electronic data which is to be kept beyond the completion of the project may be archived to protect against loss, deterioration and unauthorised use. The data set must be registered on PURE (http://www.bath.ac.uk/research/data/archiving-data/registering) and submitted to the University of Bath Research Data Archive (http://www.bath.ac.uk/research/data/archiving-data).

Paper documents may be archived at the University Records Centre. However, researchers should consider whether data is required to be kept in both an electronic and physical copies. Confidential waste paper bags can be used to dispose of paper copies once the results have been transferred to an electronic copy and the physical copies are no longer needed.

Once the data has been analysed, it will be stored by the University of Bath but will remain property of the RFU.

4.2 How will retained data be preserved? For how long?

As per the University policy all data will be kept for a minimum of 10 years. However, given that at this time all data be stripped of personal information and be anonymous it may be archived and stored indefinitely.

4.3 How will any original software be maintained after the project?

Not applicable for this study.

4.4 Will access be restricted to any retained data? Why, and how?

This data will not be made publically available. Whilst the data will be anonymous, it will remain property of the RFU. Any external requests to access the data will have to be made to the Chair of the Steering Group.

5 Implementation

5.1 How will this plan be kept up to date?

This is a working document and has been developed prior to the collection of any data. As such, there may be aspects of the document which may need to be reviewed when the collection starts. The research team will review this document on a yearly basis and provide any updates if necessary.

5.2 What special resources will this plan require, if any?

Not applicable.

5.3 What training or further information will you need, if any?

The research students in the project have recently completed a data management planning workshop and concordat to support research integrity module. However, it may be necessary for a refresher or further workshops (E.g. RDM: Sensitive data) to be completed through the project and as the document develops. The research team also appreciates the support that the library service may offer throughout the year (research-data@bath.ac.uk).

APPENDIX B - TEAM SPREADSHEET

Introduction

What is the project?
Welcome to the Youth Rugby Injury Surveillance Project, an RFU funded research project run by the University of Bath. We aim to better understand injury through surveillance.

Why take part?
By taking part, you are showing that you are committed to improving the understanding of injury in youth rugby. Once all of your data has been returned, you will be given a logo by the RFU to display on your school website.

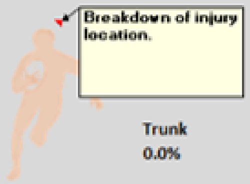
What is most important?
Please take the time to read this guide and then input data fully and correctly.

What do we do with the data?
We use injury and exposure (match & training) data to work out the risk and severity of injury across different age groups.

How do we store the data?
All data is stored on a secure, protected University. Access is limited and all data is anonymised. No individual will ever be identifiable in any work we produce.

The Workbook

Information Tab
Please fill out anything highlighted red. Once complete, it will automatically populate parts of the spreadsheet, saving you time.



Squad List Tab
Please fill in the **full name** and DOB of each player in the squad and all of the details of any staff involved in the project.
So that we can use your data, please ensure that every player and their parent has consented before the end of the season.

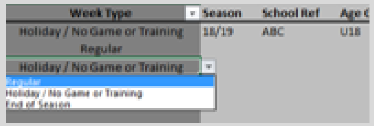
Statistics Tab
As you input data, you will receive instant feedback in the statistics tab. If you are unsure what the statistics mean, hover over the cell for an explanation.
It is important that you do not leave anyexposure or injury cells blank, or get behind on inputting data, as this will cause the statistics to be incorrect.

Guide | Information | Squad List | Exposure | Injuries | Statistics

Exposure

What do I need to record?
Rugby training sessions: Pre-season camps, lunchtime sessions, after school sessions and team training.
Rugby matches: Friendly, competitive and tournaments.

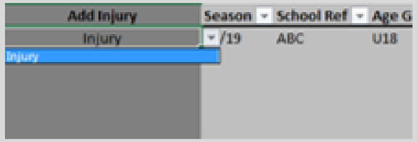
What do I need to do?
1) Complete the **team information** and **season dates** in the information tab. This will populate the "week commencing" dates.
2) Select the type of week(Regular / Holiday or No Activity / End of Season), in the "Week Type" column.
3) In the row for that week, fully and correctly fill out all training sessions and matches.
4) If taking part in a tournament, put the total time played in the minutes column.



Injuries

What do I need to record?
We are interested in injuries that **prevent a player from taking a full part** in planned training or match activities, **more than one day after the injury**.
Example: If a player is injured at a training session on Friday, but is able to play on Saturday, you do not need to record this.
Example: If a player is injured at a training session on Thursday and cannot play on Saturday, you should record this injury.

What do I need to do?
1) In the "Add Injury" Column, select "Injury".
2) Complete the details in the row for that injury. It is vital that we have a "return to play date", so please fill this in when they have returned to planned rugby activities.
3) If a player has sustained multiple injuries, please fill out one row per injury.



Guide | Information | Squad List | Exposure | Injuries | Statistics

Youth Rugby Injury Surveillance Project

University of Bath | England Rugby | Rugby Safe

School		Season Start Date	
School Code		Season End Date	
Age Group			
Team			

Individual Inputting Exposure Data

Contact Name	
Contact Email	
Contact Number	

Individual Inputting Injury Data

Contact Name	
Contact Email	
Contact Number	

School Information

School Type	
School Address	
School Post Code	

Is your school happy to be included in media articles?

Permission	
Permission Given By (Name)	
Date Completed	

If you have any questions, please feel free to contact Matt or Craig.

Email rfu-youth@bath.ac.uk
Phone 01225383617

Guide | Information | Squad List | Exposure | Injuries | Statistics

Player	Full Name (First & Surname)	DOB
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		

Staff	Full Name (First & Surname)	DOB	Role
1			
2			
3			
4			
5			

Guide | Information | **Squad List** | Exposure | Injuries | Statistics

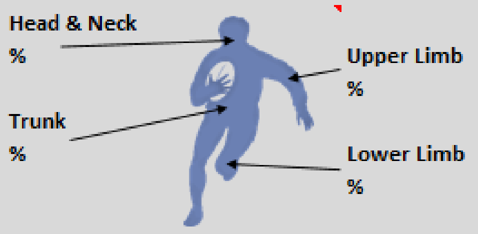
		Match 1									Match 2				
Week Type	Week Commencing	Date	Type	Mins	Opponent	Location	Surface	W/L/D	Score For	Score Against	Date	Type	Mins	Opponent	Loca

Guide | Information | Squad List | **Exposure** | Injuries | Statistics

Add Injury	Date (Injury)	Date (Return To Play)	Time Loss (Days)	Training / Match	Surface	Quarter	Injury Outcome	Position	Event Causing Injury	Acute / Gradual	Side of Body	Body Location	Injury Type	Notes

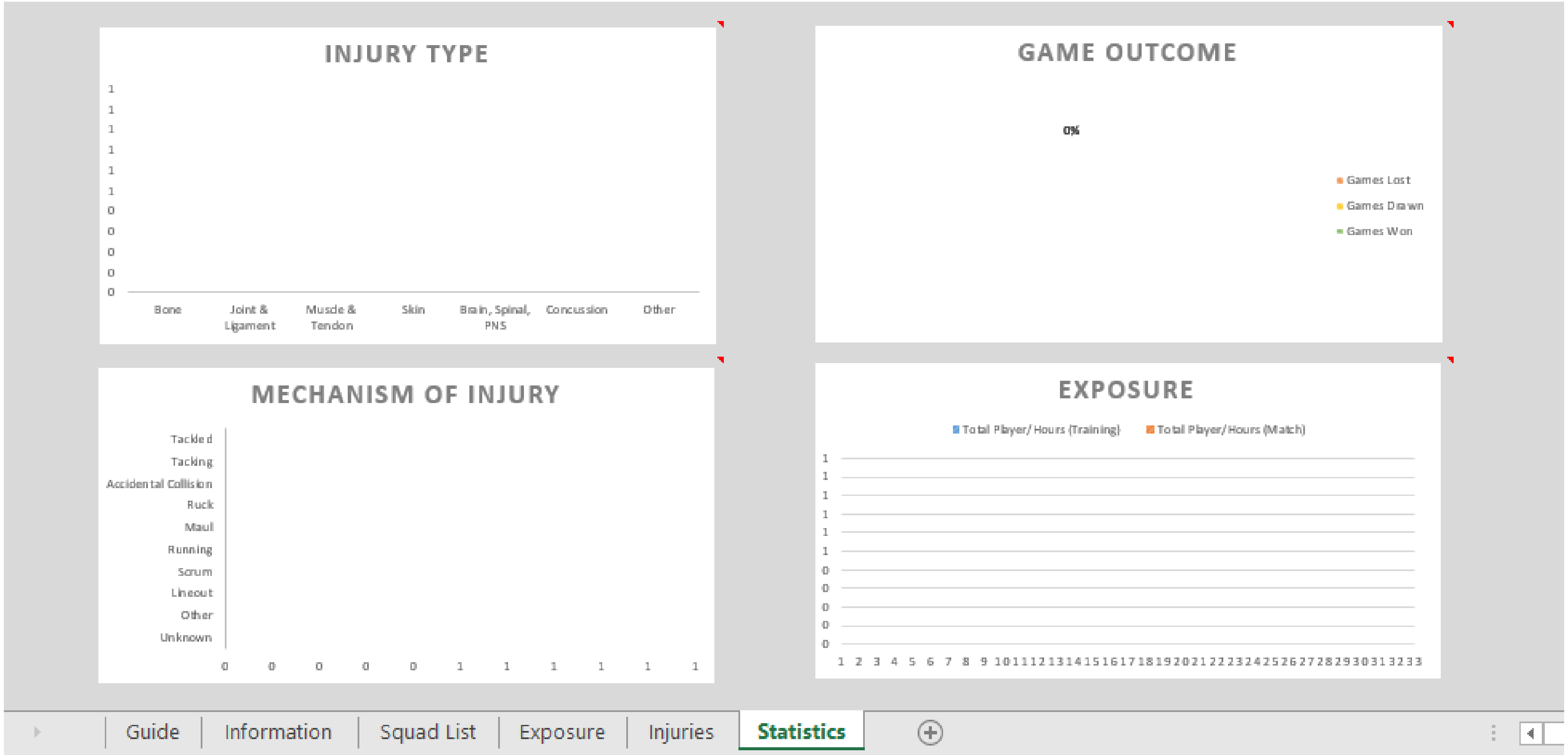
Guide | Information | Squad List | Exposure | **Injuries** | Statistics

	Overall	Training	Match
Player-Hours			
Injuries			
Total Time-Loss (Days)			
Average Time-Loss (Days)			
Player-Hours / Injury			
Injuries / 1000 Player-Hours			



Points For	Points Against	Points Difference	Injuries / Match	Matches / Injury

Guide | Information | Squad List | Exposure | Injuries | Statistics


INJURY TYPE
1
1
1
1
1
1
0
0
0
0
0
Bone
Joint & Ligament
Muscle & Tendon
Skin
Brain, Spinal, PNS
Concussion
Other
GAME OUTCOME
0%
Games Lost
Games Drawn
Games Won
MECHANISM OF INJURY
Tackled
Tacking
Accidental Collision
Ruck
Maul
Running
Scrum
Lineout
Other
Unknown
0 0 0 0 0 1 1 1 1 1 1
EXPOSURE
Total Player/Hours (Training)
Total Player/Hours (Match)
1
1
1
1
1
1
0
0
0
0
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Guide
Information
Squad List
Exposure
Injuries
Statistics

APPENDIX C - PAPER EXPOSURE FORM

RFU Schools Rugby

Injury Surveillance Project

Weekly Report Form

TO BE COMPLETED BY A COACH IN CHARGE OF EACH AGE GROUP TEAM

For enquiries / clarification, please contact:

Matt Hancock
Department for Health
University of Bath
Bath
BA2 7AY

Tel – 01225 383617
Email – rfu-youth@bath.ac.uk

School Code

Please enter this code in the **'School Ref.'** section in the top left-hand corner of each sheet used.

A. GENERAL INFORMATION

1. **TRAINING SESSION:** Training sessions we are interested in collecting information from are those involving any **rugby-related activity** that is **organised** and **run by a member of school staff** (ie: Rugby Coach / Strength and Conditioning Coach). The sessions below are those which we would be interested in collecting information about:

   - Pre-season training sessions / camps.
   - General team training (lunchtime / after-school sessions).
   - Team run through.
   - Training / trial matches between teams from the same school.

2. **MATCH:** Matches we are interested in collecting information from are any organised fixtures that take place between teams from different schools (ie: friendly / cup matches)

   NOTE- There is no need to complete a form for training sessions or matches of shortened versions of the game (7's, 10's, or tournament play where match duration is reduced).

B. GUIDANCE FOR COMPLETION OF PLAYER ATTENDANCE REPORT FORM

1. **Please try to fill out the information for a training session or match as soon as possible afterwards.**
2. Please complete a sheet for training sessions and matches in a 7-day period running from a Monday to the following Sunday.
3. **It is possible that your team might play more than 1 match or train more than 5 times in a given week. If this is the case, please complete an additional exposure report form.**
4. Please provide a date for the Monday of each week, as well as the dates of any matches and training sessions and circle the age group and teams that the form corresponds to (ie: U15a, U18c/3rd XV).
5. **For matches, please provide a date, the age group team that the match corresponds to, and the name of the opposition as well as whether the fixture was played home or away.**
6. For training sessions, please circle the teams present at the session, the length of the session and the number of players that participated.
7. **Once a weekly report form has been completed, tear the form out of the booklet and return it to the nominated data co-ordinator as soon as possible.**
8. Please return all completed forms to Bath University.
9. **Once the winter term rugby programme has finished (Last training session / match), please return any outstanding forms as soon as possible.**

RFU Schools Rugby Injury Surveillance Project - Weekly Report Form

RFU

UNIVERSITY OF BATH

School Reference [ ]

Week Commencing: Monday DD MM YYYY

Match

Age Group (Embolden and underline): 13 15 18

Team (Embolden and underline): A B C D

Embolden and underline: Home Away

Opponent: ____________________

Date: DD........... MM......... YYYY....

Score Line: For: [ ] Against: [ ]

Training

Date	DD MM	DD MM	DD MM	DD MM	DD MM
Age-group (U13 / U15 / U18)					
Team (Embolden and underline)	A B C D	A B C D	A B C D	A B C D	A B C D
Total length of session (mins)					
Total number of players in session					

RFU Schools Rugby Injury Surveillance Project

Injury Report Form

TO BE COMPLETED BY SCHOOL NURSE / PHYSIOTHERAPIST / DOCTOR

For enquiries / clarification, please contact:

Matt Hancock
Department for Health
University of Bath
Bath
BA2 7AY

Tel – 01225 383617
Email – rfu-youth@bath.ac.uk

School Code

Please enter this code in the **'School Ref.'** section in the top left-hand corner of each sheet used.

A. GENERAL INFORMATION

1. **INJURY**: The injuries we are interested in learning about are those that prevent a player taking a **FULL** part in all planned training or match activities for more than one day following the day of the injury.

2. Players being absent due to illness of other medical conditions, or through being injured from activities other than school rugby do not need to have an injury report form completed for them.

3. Please do NOT enter players' names. Insert the player's shirt number, if the injury occurred during a match. This will help to identify them during video analysis.

B. DEFINITIONS

Playing Position at time of Injury

1. Front Row – Prop, Hooker
2. Second Row - Lock
3. Back Row – Flanker, No 8
4. Half-back – Scrum- half, Fly-half
5. Inside Back – Centre
6. Outside Back – Wing, Full back

Injury Classification

1. Acute – Injury was immediately preceded by an event eg: tackling.
2. Gradual Onset – Not possible to identify the specific event at which the injury occurred, but confident that the injury was rugby-related.

C. GUIDANCE FOR COMPLETION OF INJURY REPORT FORMS

1. **Please try to fill out the information for a training session or match as soon as possible afterwards.**

2. If multiple injuries are sustained at the same time, please complete a separate Injury report form for each injury.

3. If an injury occurs without a clear time of onset, please fill in details for the last session / match the player took part in.

4. Please continue to monitor players who are still injured at the conclusion of the winter term until they are fit to return to regular training/playing where possible, even if this is in a different sport. If this is not going to be possible, please state **'Season ending'** in **'Date of return from injury'** box on Injury Report Form.

Orchard Code (Injury Classification) – As an optional piece of information, we are using the Orchard Sports Injury Coding System (OSICS), which enables precise coding of each rugby-related injury. This system involves coding the relevant diagnosis using three alphanumeric characters. The first character relates to body location, the second to injury type, and the third to the exact nature of the injury. Please refer to the complete list of codes when coding each diagnosis and ensure that you use **the most specific code**. Only one code can be entered for each injury.

When a player returns to full training / playing, please complete the date of return and return the form to the Nominated Data Co-ordinator as soon as possible.

RFU Schools Rugby Injury Surveillance Project – Injury Report Form

SCHOOL Ref: ______ PLAYER Shirt No: ______ Date of injury: DD MM YYYY Date of Return to Play: DD MM YYYY

1. ACTIVITY AT TIME OF INJURY (Please **embolden and underline** either Match **OR** Training):
(If injured during a Match, please indicate which ¼ this occurred in)

Training | Match 1/4 2/4 3/4 4/4

If Injured during a Match, please **embolden and underline** the outcome: Not Removed | Removed at time of Injury | Removed later in the Match

Embolden and underline the playing position of the player:
(Numbers below playing unit are for reference only, do not use these)

Front Row	Second Row	Back Row	Half-back	Inside Back	Outside Back
1,2,3	4,5	6,7,8	9,10	12,13	11,14,15

2. EVENT CAUSING INJURY (Please **embolden and underline** the most accurate event):

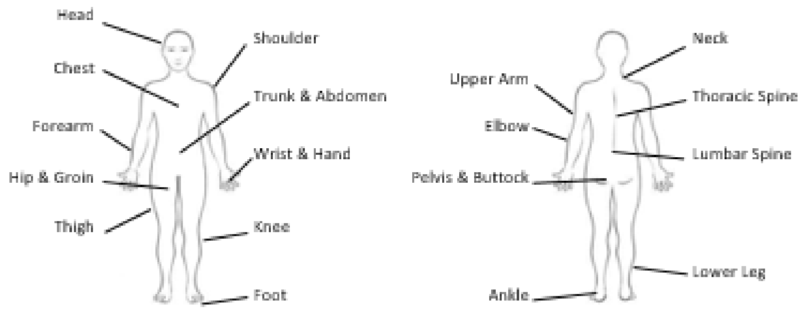
Tackled | Tackling | Accidental Collision | Ruck | Maul | Running

Scrum | Lineout | Other (Please State): ______

3. INJURY CLASSIFICATION (Please **embolden and underline** the most accurate option for each question):

Injury was: Acute | Gradual onset **Side of body injured:** Left | Right | N/A

Body Location: (Please **embolden and underline** name of injured body location)



Location Unclear / Unspecified

Injury Type: (Please **embolden and underline** name of injury type)

Concussion	Bruising / Haematoma	Cut / Abrasion
Joint (non-ligament) Injury	Ligament Injury	Joint Dislocation
Cartilage Injury	Muscle Injury	Tendon Injury
Fracture	Stress Fracture	Other stress / overuse injury
Abdominal organ injury	Nerve Injury	Vascular Injury
Non-Specific Injury	Other Injury not otherwise specified	

OPTIONAL: **Orchard Code:** ______

In as much detail as possible, please describe the injury:

YOUNG PERSON INFORMATION SHEET
Youth Rugby Injury Surveillance Project

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

We are asking you to take part in a study of injuries in young rugby players. The study is supported by the Rugby Football Union. Before deciding whether you want to take part, you should know why we are doing the study and how it will affect you.

Read the information carefully and if there is anything that you do not understand, please speak to a member of your rugby programme (coach / doctor / nurse / physiotherapist) or contact us. When you have read and understood the information, if you wish to be in the study, you will be asked to sign a form to confirm this.

1. Why are we doing this research project:

Rugby is one of the most popular sports played in this country. As with all sports, there are risks involved with rugby and it is important to make the game as safe as possible.

This study aims to follow a number of school rugby teams and to collect information about any rugby-related injuries that are suffered during this time. This will allow us to work out the risk of injury and help us to prevent injury in the future.

Your school will be shown a rugby warm-up that has been shown to reduce injuries and we will be looking at how well this works. We will also be filming some school rugby matches, which we will look at to better understand the demands of the game at your age group.

2. Why have you been asked to take part?

We are studying school rugby teams from the under-13 to under-18 age groups. Your school coach has agreed to be involved, but we also need to make sure that you are happy to take part. It is important that you understand what it involves and how it may impact you.

3. Do I have to take part?

It is up to you whether you take part in the study. If you want to take part, you must complete a form that confirms you have read this information and agree to be included in the study. Both you and your parent / guardian will need to consent if you wish to take part in the study. You can withdraw from the study by contacting the research team at any time, without giving a reason.

4. **What would taking part involve?**

In pre-season we will ask you to complete a questionnaire asking about your playing history and beliefs about injuries. Your coaches may monitor your attendance at rugby matches and training. If you suffer an injury during school rugby training or a match, you should let your coach know so that information about the injury can be collected.

5. **What are the benefits of taking part?**

Your coach will receive information about your team's training and injuries. Certain schools will also be given free footage of their games, which can be used for coaching purposes.

6. **Will my matches filmed and what happens to the footage?**

Your school may want to have your matches filmed. This footage will be available to the coaching staff of both competing teams for coaching purposes and to the University for Match Analysis. We will look to better understand the number of events in each game and characteristics of the tackle, but will not be looking at any particular individual's performance. Only the research staff at the University of Bath will have access to this footage. Your coaches can use the footage for analysis, but are not permitted to share the file.

7. **What are the possible disadvantages and risks of taking part?**

You won't be asked to do anything that is different from your normal rugby participation, so there are no additional risks. However, should you have any concerns please speak to your coach, parent or guardian and contact the research team if necessary.

8. **Will taking part involve any discomfort or embarrassment?**

We do not expect you to feel any discomfort or embarrassment during the study. No direct reference will be made to you, nor at any point will any footage be made available to the public.

9. **Who will have access to the information that I provide?**

All information that is collected will be stored securely. Any information that has identifiable information on it will only be accessible to the research team at the University of Bath.

10. **What will happen to the data collected and results of the project?**

The information will be anonymised and analysed by researchers at the University of Bath. We will produce a report and write scientific articles about the current risks of injury in youth rugby. However, no personal references to you will be made in any report.

11. Who has reviewed the project?

This project has been given a favourable opinion by the University of Bath, Research Ethics Approval Committee for Health (REACH) [reference: XXXXXXXXX].

11. How can I stop taking part in the project after it has started?

You can withdraw your participation in the study at any time by emailing the research team at rfu-youth@bath.ac.uk. If you withdraw no additional data will be collected relating to you but data previously collected will remain in the study.

12. What happens if there is a problem?

If you have a concern about any aspect of the project you should speak to your coach, parent or guardian to see if they are able to answer your question. If they are not please contact the research team, using the contact details at the bottom of the page.

If you wish to make a complaint, please contact the Chair of the Research Ethics Approval Committee for Health:

Dr James Betts
Email: J.Betts@bath.ac.uk
Tel: 01225 383 448

13. If I require further information who should I contact and how?

You can contact Craig Barden and/or Matt Hancock at the University of Bath who will be happy to answer any questions that you have. Please do also talk to your parent/guardian about your decision whether to take part in the project.

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

PARENT/GUARDIAN INFORMATION SHEET
Youth Rugby Injury Surveillance Project

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

We are asking your child to take part in a study of injuries in young rugby players. The study is supported by the Rugby Football Union. Before deciding whether you want your child to take part, you should know why we are doing the study and how it will affect you / your child. Take time to the read the information carefully. If there is anything that you do not understand, please speak to a member of your rugby programme (coach / doctor / nurse / physiotherapist) or contact us for further information. When you have read and understood the information, if you wish your child to be included in the study, you will be asked to sign a Consent Form.

1. What is the purpose of the project:

Rugby is one of the most popular sports played in this country. As with all sports, there are risks involved with rugby and it is in the interest of all stakeholders to make the game as safe as possible.

This study aims to follow a number of school rugby teams and to collect information about any rugby-related injuries that are suffered during this time. This will allow us to measure the level of injury risk and highlight any areas where injuries may be prevented in the future.

Your child's school will be shown a rugby warm-up that has been shown to reduce injuries. We are looking to further investigate the usage and effectiveness of this programme. We will also be filming some school rugby matches, which we will analyse to better understand the physical demands of the game at different age groups.

2. Why has my child been selected to take part?

We are looking to study school rugby teams from under-13 to under-18 age groups. Your child's school team has agreed to take part as your coaches see the potential benefit that this study may have. However, as a parent/guardian it is important that you understand what the study involves and how it may impact you and your child.

3. Does my child have to take part?

It is up to you whether your child takes part in the study. If you want your child to take part, you must sign a consent form that confirms you have read this information and you agree for your child to be included in the study. Both you and your child will need to consent if you wish to take part in the study. You can withdraw from the study by contacting the team coach or the research team at any time, without giving a reason, using the contact details at the bottom.

4. What will my child have to do?

We will not ask your child's coach to alter anything to do with your child's training or matches. In pre-season we will ask your child to complete a questionnaire asking about their playing history and beliefs towards injuries. If your child suffers an injury during school rugby training or a match, you or your child should let the coach know so that information about the injury can be collected and your child can be treated.

5. What are the benefits of taking part?

When completing the report form electronically, the school will automatically receive feedback and data about the team's exposure and the number, type and mechanism of injuries. Certain schools will also be given free footage of their games, which can be used for coaching purposes.

6. Will the matches filmed and what happens to the footage?

The school may opt to have your child's matches filmed. The University uses an external company who will organise filming directly with the school and will attend their games. This footage will be available to the coaching staff of both competing teams for coaching purposes and to the University for Match Analysis. We will look to better understand the number of events in each game and characteristics of the tackle, but will not be looking at any particular individual's performance. Only the research staff at the University of Bath will have access to this footage. The coach can use this footage for analysis, but is not permitted to share the file.

7. What are the possible disadvantages and risks of taking part?

Your child won't be asked to do anything that differs from their normal rugby participation, so there are no additional risks. However, should you have any concerns please speak to your child's coach or contact the research team if necessary.

7. Will my child's participation involve any discomfort or embarrassment?

We do not expect your child to feel any discomfort or embarrassment during the study. No direct reference will be made to your child in any of the injury data or match analysis, nor at any point will these matches be made publically available.

8. Who will have access to the information that my child provides?

The General Data Protection Regulation says that we must have your permission to collect information about your child during the course of this study. All information collected is stored securely and any information that relates to you or your child will be accessible only to the research team at the University of Bath.

9. What will happen to the data collected and results of the project?

The information will be anonymised and analysed by researchers at the University of Bath. We will produce a report and write scientific articles about the current risks of injury in youth rugby. However, no personal references to your child will be made in any report. Data will be kept for a minimum of ten years, after which it may be kept but will be anonymised.

10. Who has reviewed the project?

This project has been given a favourable opinion by the University of Bath, Research Ethics Approval Committee for Health (REACH) [reference: XXXXXXXXX].

11. How can I withdraw my child from the project?

You can withdraw your child's participation in the study at any time by contacting the research team at rfu-youth@bath.ac.uk. If you withdraw your child, no additional data will be collected relating to them but data previously collected will remain in the study.

12. What happens if there is a problem?

If you have a concern about any aspect of the project you should speak to your child's coach to see if they are able to answer your question. If they are not please contact the research team directly.

If you wish to make a complaint, please contact the Chair of the Research Ethics Approval Committee for Health...

Dr James Betts
Email: J.Betts@bath.ac.uk
Tel: 01225 383 448

13. If I require further information who should I contact and how?

You can contact Craig Barden and/or Matt Hancock at the University of Bath who will be happy to answer any questions that you have.

Name of Researchers: Craig Barden, Matt Hancock
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Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

UNIVERSITY OF BATH

COACH INFORMATION SHEET
Youth Rugby Injury Surveillance Project

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

We are asking you to take part in a study of injuries in young Rugby players. The study is supported by the Rugby Football Union. Before deciding whether you want to take part, you should know why we are doing the study and how it will affect you. Take time to the read the information carefully. If there is anything that you do not understand, please speak to a member of research team for further information. When you have read and understood the information, if you wish to be in the study, you will be asked to sign a Coach Consent Form, as we will be using data provided by both you and your team

1. Why are we doing this research project:

Rugby is one of the most popular sports played in this country. As with all sports, there are risks involved with rugby and it is in the interest of all stakeholders to make the game as safe as possible.

This study aims to follow a number of school rugby teams and to collect information about any rugby-related injuries that are suffered during this time. This will allow us to measure the level of injury risk and highlight any areas where injuries may be prevented in the future.

Your school will be shown a rugby warm-up that has been shown to reduce injuries. We are looking to further investigate the usage and effectiveness of this programme. We will also be filming some school rugby matches, which we will analyse to better understand the physical demands of the game at different age groups.

2. Why have you been asked to take part?

We are looking to study school rugby teams from under-13 to under-18 age groups. Your school team has expressed an interest in the study as they see the potential benefit that this study may have. However, as you will be directly participating in the study it is important that you understand what the study involves and how it may impact you.

3. Do I have to take part?

It is up to you whether you take part in the study. If you want to take part, you must sign a consent form that confirms you have read this information and you agree for him to be included in the study. You can withdraw from the study by contacting the research team at any time, without giving a reason, using the contact details at the bottom.

4. What would taking part involve?

In pre-season we will ask you to complete a questionnaire asking about your coaching history and beliefs towards injuries. We will also provide you with an opportunity to attend a workshop on a rugby-specific warm-up programme. Throughout the season we will ask you to report back to us on your team's training, matches and any injuries that are sustained, before completing a post-season questionnaire.

5. What are the benefits of taking part?

When completing the report form electronically, it will automatically give you feedback and data about your team's exposure and the number, type and mechanism of injuries. Certain schools will also be given free footage of their games, which can be used for coaching purposes.

6. Can I have my matches filmed and what happens to the footage?

You are able to have your games filmed. The University uses an external company who will organise filming with you directly and will attend your games. This footage will be available to you for coaching purposes and to the University for Match Analysis. We will look to better understand the number of events in each game and characteristics of the tackle, but will not be looking at any particular individual's performance. Only the research staff at the University of Bath will have access to this footage. Once you have been given access to the footage, you are welcome to use this for analysis and to show it to the players, but are not permitted to share the file.

7. What are the possible disadvantages and risks of taking part?

There are no perceived risks for you in taking part in this study. However, should you have any concerns please contact the research team.

8. Who will have access to the information that I provide?

The General Data Protection Regulation says that we must have your permission to collect information during the course of this study. All information collected is stored securely and any information that identifies you or your team will be accessible only to the research team at the University of Bath.

9. What will happen to the data collected and results of the project?

The information will be analysed by researchers at the University of Bath. We will produce a report and write scientific articles about the current risks of injury in youth rugby. However, no personal references to you or your team will be made in any report. Data will be kept for a minimum of ten years, after which it may be kept but will be anonymised.

10. Who has reviewed the project?

This project has been given a favourable opinion by the University of Bath, Research Ethics Approval Committee for Health (REACH) [reference: XXXXXXXXX].

10. How can I stop taking part in the project after it has started?

You can withdraw your participation in the study at any time by sending an email with your name and date of birth to rfu-youth@bath.ac.uk. If you withdraw no additional data will be collected relating to you but data previously collected will remain in the study.

11. What happens if there is a problem?

If you have a concern about any aspect of the project you should contact the research team directly through the contact details at the bottom of the page.

If you wish to make a complaint, please contact the Chair of the Research Ethics Approval Committee for Health...

Dr James Betts
Email: J.Betts@bath.ac.uk
Tel: 01225 383 448

12. If I require further information who should I contact and how?

You can contact Craig Barden and/or Matt Hancock at the University of Bath who will be happy to answer any questions that you have.

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

APPENDIX H - PLAYER ASSENT FORM

YOUNG PERSON'S ASSENT FORM
Youth Rugby Injury Surveillance Project

UNIVERSITY OF BATH

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Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

	Please Intial
1. I have read and understand the information about this study and I have had a chance to ask any questions that I have.	☐
2. I have received answers to any questions that I have.	☐
3. I give consent for researchers to collect information and record footage of any matches that I play for the school.	☐
4. I agree for my coach and school medical centre to provide information on any injuries that I have during school rugby to the research team at the University of Bath.	☐
5. I agree that the information will only be used for research and in a report to my school/club. I won't be identified.	☐
6. I understand that if my Parent or Guardian requests that I stop taking part, my involvement in the project will be stopped.	☐
7. I understand the information I provide will be held in line with the General Data Protection Regulation.	☐
8. I understand that I can withdraw from this study at any time, without being asked why, by contacting the research team through the contact details at the top of the page.	☐
9. I understand that if I withdraw from the study, no additional data will be collected relevant to me but data previously received will still be used.	☐
10. I understand that my data will be kept for a minimum of ten years. After which it may be kept, but will be made anonymous.	☐
11. I agree to take part in this project.	☐

Your name: (First & Surname)	______________________	**Date of Birth:** (DD/MM/YYY)	______________
School Name:	______________________	**School Team:** (eg.U13)	______________
Your Height: (cm)	______________________	**Your Weight:** (kg)	______________
Your signature:	______________________	**Today's Date:** (DD/MM/YYY)	______________

If you decide that you no longer wish to take part in this study, or if you have any questions/concerns, please contact the research team at rfu-youth@bath.ac.uk, 01225 383 617.

If you have any concerns or complaints related to your participation in this project please direct them to the Chair of the Research Ethics Approval Committee for Health, Dr James Betts (j.betts@bath.ac.uk, 01225 383448

APPENDIX I - PARENT / GUARDIAN CONSENT FORM

PARENT/GUARDIAN CONSENT FORM
Youth Rugby Injury Surveillance Project

UNIVERSITY OF BATH

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

Please Intial

1. I have read and understand the information about this study and I have had a chance to ask any questions that I have. ☐
2. I have received answers to any questions that I have. ☐
3. I give consent for researchers to collect information and to record footage of any matches that my child plays for the school. ☐
4. I agree for the school coach and medical centre to provide information on any relevant injuries that my child sustains during school rugby to the research team at the University of Bath. ☐
5. I agree that the information will only be used for research purposes and in a report to my child's school/club. This data will be anonymous. ☐
6. I understand my child will be asked if they agree to participate and if they choose not to, their decision will be respected. ☐
7. I understand the information that is provided will be held in line with the General Data Protection Regulation. I understand that I am free to withdraw my child's data within two weeks of starting participation. ☐
8. I understand that I can withdraw my child from this study at any time, without being asked why, by contacting the research team through the contact details at the bottom of the page. ☐
9. I understand that if I withdraw my child from the study, no additional data will be collected relevant to them but data previously received will still be used. ☐
10. I understand that my child's data will be kept for a minimum of ten years. After which it may be kept, but will be anonymised. ☐
11. I hereby fully and freely consent to my child's participation in this project. ☐

Your name: (First & Surname)	______________________________		
Child's name: (First & Surname)	____________	**Child's Date of Birth:** (DD/MM/YYY)	____________
School Name:	____________	**School Team:** (eg.U13)	____________
Child's Height: (cm)	____________	**Child's Weight:** (kg)	____________
Your signature:	____________	**Today's Date:** (DD/MM/YYY)	____________

If you decide that you no longer wish to take part in this study, or if you have any questions/concerns, please contact the research team at rfu-youth@bath.ac.uk, 01225 383 617.

If you have any concerns or complaints related to your participation in this project please direct them to the Chair of the Research Ethics Approval Committee for Health, Dr James Betts (j.betts@bath.ac.uk, 01225 383448).

APPENDIX J - COACH CONSENT FORM

COACH CONSENT FORM
Youth Rugby Injury Surveillance Project

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

	Please Intial
1. I have read and understand the information about this study and I have had a chance to ask any questions that I have.	☐
2. I have received answers to any questions that I have.	☐
3. I agree that the information will only be used for research purposes and in a report to my school/club.	☐
4. I understand the information I provide will be held in line with the General Data Protection Regulation.	☐
5. I understand that if my matches are filmed I will be given access to this footage. It is my responsibility to ensure that they are stored securely and that access is controlled.	☐
6. I understand that I can withdraw from this study at any time, without being asked why, by contacting the research team through the contact details at the bottom of the page.	☐
7. I understand that if I withdraw from the study, no additional data will be collected relevant to me but data previously received will still be used.	☐
8. I understand that this data will be kept for a minimum of ten years. After which it may be kept, but will be anonymised.	☐
9. I understand and acknowledge that the investigation is designed to promote scientific knowledge and that the University of Bath will use the data I provide only for the purpose(s) set out in the information sheet.	☐
10. I hereby fully and freely consent to my participation in this project.	☐

Your name: (First & Surname)	______________________	**Date of Birth:** (DD/MM/YYY)	______________
School Name:	______________________	**School Team:** (eg.U13)	______________
Your signature:	______________________	**Today's Date:** (DD/MM/YYY)	______________

If you decide that you no longer wish to take part in this study, or if you have any questions/concerns, please contact the research team at rfu-youth@bath.ac.uk, 01225 383 617.

If you have any concerns or complaints related to your participation in this project please direct them to the Chair of the Research Ethics Approval Committee for Health, Dr James Betts (j.betts@bath.ac.uk, 01225 383448).

APPENDIX K - OPPOSITION TEAM COACH CONSENT FORM

OPPOSITION TEAM COACH CONSENT FORM
Youth Rugby Injury Surveillance Project

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

Name of Supervisors: Prof Keith Stokes, Dr Carly McKay, Dr Simon Roberts
Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

Please Intial

1. The University of Bath, supported by the RFU, are collecting match footage from the team you are about to play, as part of the Youth Rugby Injury Surveillance Project. ☐
2. I understand that the footage is not being collected to analyse my team. ☐
3. I understand that this footage will be used for match analysis only, in order to better understand the number of events in the game and characteristics of the tackle. ☐
4. I agree that this data is collected for research purposes and understand that neither your school, team or players will be individually identified in any reports or scientific articles. ☐
5. I understand the match footage will be held in line with the General Data Protection Regulation and only researchers at the University of Bath will have access to this footage. ☐
6. I understand that if my matches are filmed I will be given access to this footage. It is my responsibility to ensure that they are stored securely and that access is controlled. ☐
7. I understand that this data will be kept for a minimum of ten years. ☐
8. I understand and acknowledge that the investigation is designed to promote scientific knowledge and that the University of Bath will use the data I provide only for the purpose(s) set out above. ☐
9. I hereby fully and freely consent to my team having their match filmed. ☐

Your name: (First & Surname)	______________________	**Your role:**	______________
School Name:	______________________	**School Team:** (eg.U13)	______________
Your signature:	______________________	**Today's Date:** (DD/MM/YYY)	______________

If you decide that you no longer wish to take part in this study, or if you have any questions/concerns, please contact the research team at rfu-youth@bath.ac.uk, 01225 383 617.

If you have any concerns or complaints related to your participation in this project please direct them to the Chair of the Research Ethics Approval Committee for Health, Dr James Betts (j.betts@bath.ac.uk, 01225 383448).

APPENDIX L - MATCH OFFICIAL CONSENT FORM

MATCH OFFICIAL CONSENT FORM
Youth Rugby Injury Surveillance Project

UNIVERSITY OF BATH

Name of Researchers: Craig Barden, Matt Hancock
Contact details of Researchers: rfu-youth@bath.ac.uk (01225 383 617)

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Contact details of Supervisors: K.Stokes@bath.ac.uk, C.D.McKay@bath.ac.uk, S.Roberts@bath.ac.uk

	Please Intial
1. The University of Bath, supported by the RFU, are collecting match footage as part of the Youth Rugby Injury Surveillance Project.	☐
2. I understand that the footage is not being collected to analyse any match official.	☐
3. I understand that this footage will be used for match analysis only, in order to better understand the number of events in the game and characteristics of the tackle.	☐
4. I agree that this data is collected for research purposes and understand that I will not be individually identified in any reports or scientific articles.	☐
5. I understand the match footage will be held in line with the General Data Protection Regulation and only researchers at the University of Bath will have access to this footage.	☐
6. I understand that this data will be kept for a minimum of ten years.	☐
7. I understand and acknowledge that the investigation is designed to promote scientific knowledge and that the University of Bath will use the data I provide only for the purpose(s) set out above.	☐
8. I hereby fully and freely consent to the filming of the match.	☐

Your name: (First & Surname) ____________________ **Your role:** ____________

Your signature: ____________________ **Today's Date:** (DD/MM/YYY) ____________

If you decide that you no longer wish to take part in this study, or if you have any questions/concerns, please contact the research team at rfu-youth@bath.ac.uk, 01225 383 617.

If you have any concerns or complaints related to your participation in this project please direct them to the Chair of the Research Ethics Approval Committee for Health, Dr James Betts (j.betts@bath.ac.uk, 01225 383448).

APPENDIX M - INJURY TYPES TABLE

	Under-13				Under-15				Under-18				Overall			
	n	**Incidence, injuries/1000h (95% CI)**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI)**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**
Type																
Nerve	7	5.6 (2.7-11.7)	23 (6-41)	129 (62-272)	31	6.4 (4.5-9.1)	25 (16-35)	162 (114-230)	120	9.7 (8.1-11.6)	29 (24-35)	284 (238-340)	158	8.5 (7.3-10.0)	28 (23-33)	241 (206-281)
- Concussion	6	4.8 (2.1-10.6)	26 (5-47)	125 (56-278)	31	6.4 (4.5-9.1)	25 (16-35)	162 (114-230)	114	9.2 (7.7-11.1)	30 (24-36)	273 (227-328)	151	8.2 (7.0-9.6)	29 (24-34)	233 (199-274)
Ligament	2	-	-	-	12	2.5 (1.4-4.4)	24 (8-39)	59 (34-104)	76	6.1 (4.9-7.7)	33 (25-42)	204 (163-256)	90	4.9 (4.0-6.0)	32 (24-39)	155 (126-190)
Muscle	3	2.4 (0.8-7.4)	14 (0-31)	34 (11-106)	14	2.9 (1.7-4.9)	10 (4-17)	30 (18-51)	50	4.0 (3.1-5.3)	18 (13-23)	71 (54-94)	67	3.6 (2.9-4.6)	16 (12-20)	58 (46-74)
Bruising / Haematoma	5	4.0 (1.7-9.5)	14 (2-27)	57 (24-137)	14	2.9 (1.7-4.9)	10 (4-15)	28 (16-47)	35	2.8 (2.0-3.9)	10 (6-13)	27 (19-37)	54	2.9 (2.2-3.8)	10 (7-13)	29 (22-38)
Fracture	3	2.4 (0.8-7.4)	60 (0-129)	144 (46-446)	20	4.1 (2.7-6.4)	66 (28-103)	271 (175-421)	32	2.6 (1.8-3.7)	53 (31-75)	136 (96-193)	55	3.0 (2.3-3.9)	55 (37-72)	162 (125-212)
Joint (Non-Ligament)	1	-	-	-	10	2.1 (1.1-3.8)	30 (9-51)	63 (34-117)	31	2.5 (1.8-3.6)	31 (18-43)	77 (54-109)	42	2.3 (1.7-3.1)	31 (20-41)	70 (52-95)
Joint Dislocation	1	-	-	-	4	0.8 (0.3-2.2)	31 (0-67)	26 (10-69)	24	1.9 (1.3-2.9)	41 (20-61)	78 (53-117)	29	1.6 (1.1-2.3)	39 (21-56)	61 (42-87)
Cut / Abrasion	1	-	-	-	3	0.6 (0.2-1.9)	15 (0-33)	10 (3-30)	17	1.4 (0.9-2.2)	11 (6-17)	15 (10-25)	21	1.1 (0.7-1.7)	12 (7-17)	14 (9-21)
Non-Specific	2	-	-	-	4	0.8 (0.3-2.2)	6 (0-11)	5 (2-21)	9	0.7 (0.4-1.4)	15 (5-24)	11 (6-20)	15	0.8 (0.5-1.3)	11 (5-16)	9 (5-14)
Tendon	0	-	-	-	0	-	-	-	8	0.6 (0.3-1.3)	16 (2-30)	10 (5-20)	8	0.4 (0.2-0.9)	16 (2-30)	7 (3-14)
Cartilage	0	-	-	-	2	-	-	-	7	0.6 (0.3-1.2)	38 (5-71)	21 (10-45)	9	0.5 (0.3-0.9)	32 (6-58)	16 (8-30)
Other	0	-	-	-	2	-	-	-	6	0.5 (0.2-1.1)	17 (3-31)	8 (4-19)	8	0.4 (0.2-0.9)	32 (7-39)	10 (5-20)
Stress Fracture	0	-	-	-	0	-	-	-	2	-	-	-	2	-	-	-
Other Stress / Overuse	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-
Abdominal / Organ	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-
Vascular	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-
Unknown	1	-	-	-	3	-	-	-	12	-	-	-	16	-	-	-

Note: Injury types are ordered based on the under-18 injury incidence. Incidence, severity and burden are not displayed where n<3.

APPENDIX N - INJURY SITES TABLE

	Under-13				Under-15				Under-18				Overall			
	n	**Incidence, injuries/1000h (95% CI)**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI)**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**	**n**	**Incidence, injuries/1000h (95% CI**	**Severity, mean days (95% CI)**	**Burden, days/1000h (95% CI)**
Site																
Head	6	4.8 (2.1-10.6)	26 (5-47)	125 (56-278)	41	8.5 (6.2-11.5)	23 (16-31)	197 (145-268)	148	11.9 (10.2-14.0)	25 (20-29)	296 (252-348)	195	10.5 (9.2-12.1)	24 (21-28)	258 (224-297)
Shoulder	4	3.2 (1.2-8.5)	24 (0-48)	76 (29-203)	17	3.5 (2.2-5.7)	21 (9-33)	74 (46-119)	52	4.2 (3.2-5.5)	32 (22-41)	133 (101-174)	73	3.9 (3.1-5.0)	29 (21-36)	114 (90-143)
Ankle	0	-	-	-	6	1.2 (0.6-2.8)	56 (0-119)	69 (31-154)	47	3.8 (2.8-5.0)	38 (25-51)	143 (107-190)	53	2.9 (2.2-3.8)	39 (26-52)	112 (86-147)
Knee	6	4.8 (2.1-10.6)	14 (3-25)	66 (30-147)	5	1.0 (0.4-2.5)	11 (1-20)	11 (5-26)	45	3.6 (2.7-4.9)	35 (23-48)	128 (96-171)	56	3.0 (2.3-3.9)	30 (21-39)	90 (69-117)
Wrist & Hand	3	2.4 (0.8-7.4)	37 (0-78)	87 (28-271)	14	2.9 (1.7-4.9)	33 (13-54)	97 (57-163)	37	3.0 (2.2-4.1)	39 (25-53)	116 (84-160)	54	2.9 (2.2-3.8)	37 (26-49)	109 (84-143)
Thigh	3	2.4 (0.8-7.4)	10 (0-21)	23 (7-71)	4	0.8 (0.3-2.2)	5 (0-9)	4 (1-10)	31	2.5 (1.8-3.6)	14 (9-19)	35 (24-49)	38	2.1 (1.5-2.8)	12 (8-16)	25 (19-35)
Neck	1	-	-	-	4	0.8 (0.3-2.2)	4 (0-7)	3 (1-8)	14	1.1 (0.7-1.9)	23 (11-36)	26 (16-44)	19	1.0 (0.7-1.6)	19 (10-27)	19 (12-30)
Lower Leg	0	-	-	-	7	1.4 (0.7-3.0)	17 (0-33)	24 (11-50)	14	1.1 (0.7-1.9)	21 (9-32)	24 (14-40)	21	1.1 (0.7-1.7)	20 (10-29)	22 (15-34)
Hip & Groin	0	-	-	-	2	-	-	-	8	0.6 (0.3-1.3)	20 (5-35)	13 (7-26)	10	0.5 (0.3-1.0)	22 (7-37)	12 (6-22)
Lumbar Spine	1	-	-	-	3	0.6 (0.2-1.9)	39 (0-84)	24 (8-76)	7	0.6 (0.3-1.2)	19 (2-35)	11 (5-22)	11	0.6 (0.3-1.1)	25 (9-42)	15 (8-27)
Foot	1	-	-	-	6	1.2 (0.6-2.8)	34 (7-61)	42 (19-93)	5	0.4 (0.2-1.0)	5 (0-10)	2 (1-5)	12	0.6 (0.4-1.1)	25 (10-41)	16 (9-29)
Chest	1	-	-	-	2	-	-	-	4	0.3 (0.1-0.9)	14 (0-28)	5 (2-12)	7	0.4 (0.2-0.8)	30 (8-51)	11 (5-23)
Elbow	0	-	-	-	1	-	-	-	3	0.2 (0.1-0.8)	26 (0-55)	6 (2-19)	4	0.2 (0.1-0.6)	26 (0-55)	6 (2-15)
Upper Arm	0	-	-	-	1	-	-	-	3	0.2 (0.1-0.8)	18 (0-38)	4 (1-13)	4	0.2 (0.1-0.6)	35 (1-70)	8 (3-20)
Forearm	0	-	-	-	2	-	-	-	2	-	-	-	4	0.2 (0.1-0.6)	15 (0-35)	3 (1-8)
Thoracic Spine	0	-	-	-	1	-	-	-	2	-	-	-	3	0.2 (0.1-0.5)	15 (0-32)	2 (1-8)
Trunk & Abdomen	0	-	-	-	2	-	-	-	1	-	-	-	3	0.2 (0.1-0.5)	8 (0-18)	1 (0-4)
Pelvis & Buttock	0	-	-	-	0	-	-	-	1	-	-	-	1	-	-	-
Unknown	0	-	-	-	1	-	-	-	5	-	-	-	6	-	-	-

Note: Injury sites are ordered based on the under-18 injury incidence. Incidence, severity and burden are not displayed where n<3.

APPENDIX O - UNKNWOWN HEAD CONTACT EXAMPLES

U13

U15

U18