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Injury Risk Factors and Preventive Strategies in Schoolboy Rugby Union

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INJURY RISK FACTORS AND PREVENTIVE STRATEGIES IN SCHOOLBOY RUGBY UNION

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ABSTRACT

The injury risk associated with schoolboy Rugby has been raised as a matter of public concern, leading to calls to formulate appropriate preventive strategies. Consequently, this programme of research was undertaken to investigate characteristics that might influence injury risk in schoolboy rugby players, as well as interventions to reduce injury risk.

The first study of this thesis (Chapter Three) presents a two-season prospective cohort study, which identifies several anthropometric characteristics and physical fitness components associated with injury risk in schoolboy Rugby players. Chapter Four outlines a staged approach to formulating a preventive exercise programme for use in schoolboy Rugby based on scientific evidence, expert knowledge, and end user opinion. In Chapter Five, the efficacy of a preventive exercise programme to reduce injury risk in schoolboy Rugby players is evaluated, demonstrating clinically meaningful reductions in concussion risk when compared with a standardised control exercise programme. In addition, greater programme compliance and dose are found to accentuate reductions across many match-derived injury outcomes measures. Finally, Chapter Six highlights meaningful associations between coach-related psychosocial factors and coaches' compliance with using a preventive exercise programme, which may be useful in future with formulating strategies to enhance compliance with programme use.

To summarise, this thesis addresses the identification of potentially modifiable risk factors and applies a novel approach to reduce injury risk in schoolboy Rugby players, emphasises the importance of compliance and dose in moderating the influence of preventive exercise programme efficacy, and outlines the associations between coach-related psychosocial factors and coaches' compliance with using a preventive exercise programme in a schoolboy Rugby population.

PUBLICATIONS

Hislop, M. D., Stokes, K. A., Williams, S., McKay, C. D., England, M., Kemp, S. P. T., & Trewartha, G. (2016). The efficacy of a movement control exercise programme to reduce injuries in youth rugby: a cluster randomised controlled trial. *BMJ Open Sport & Exercise Medicine*, *2*(1), e000043. doi:10.1136/bmjsem-2015-000043.

Hislop, M. D., Stokes, K. A., Williams, S., McKay, C. D., England, M., Kemp, S. P. T., & Trewartha, G. (2017). Reducing musculoskeletal injury and concussion risk in schoolboy rugby players with a pre-activity movement control exercise programme: a cluster randomised controlled trial. *British Journal of Sports Medicine.* Published Online First: 17 May 2017. doi: 10.1136/bjsports-2016-097434

CONFERENCE PRESENTATIONS

Hislop, M. D., Stokes, K. A., England, M., Kemp, S. P. T., & Trewartha, G. (2015). Performance on the Functional Movement Screen in youth rugby players. *8th World Congress on Science and Football*. Copenhagen, Denmark.

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CHAPTER ONE

Introduction

1.1   Research Context

Rugby Union is among the most popular team sports played worldwide throughout youth to senior levels. The sport is believed to have originated from the English school system during the early 19th century.

Participation in Rugby Union (hereafter referred to as 'Rugby') remains popular amongst young sportspeople, with recent estimates by Sport England suggesting that almost 170,000 people aged 14-25 years in England (2.1% of demographic) regularly participated in organised Rugby at least once a week during the period April 2015 to March 2016 (Sport England, 2016). However, the game at youth levels has come under increased public concern of late due to the associated risk of injury to players perceived as being too high (Carter, 2015). These concerns have contributed to elevated scrutiny surrounding the safeguarding of children (Freitag, Kirkwood, & Pollock, 2015a; Freitag, Kirkwood, Scharer, Ofori-Asenso, & Pollock, 2015b), and notably a proposal to the UK government to intervene in removing high-risk contact events such as the tackle in UK schools Rugby (Pollock & Kirkwood, 2016). Hence, it is imperative that stakeholders involved in Rugby provision can demonstrate that appropriate initiatives have been devised and implemented to minimise the risk of injury to players.

According to the "sequence of prevention" and the more recent "translating research into prevention practice" (TRIPP) frameworks proposed by van Mechelen with colleagues (1992), and Finch (2006) respectively, the process of preventing injuries starts with ascertaining the magnitude of the injury problem within sporting populations through surveillance research, before identifying the aetiological (causal) basis from which injuries occur. From there, preventive measures may then be developed and implemented through various stages. Much of the Rugby-related injury literature is comprised of descriptive epidemiological studies, with few documented studies that have moved beyond describing the level of injury risk or the events and circumstances associated with injuries and into mechanistic and

intervention studies. Furthermore, most studies have been conducted at the adult professional and community levels of the game, with fewer studies documenting injury incidence and severity across youth playing levels. The specific details surrounding injury types and events that would be useful in designing preventive measures or highlighting particularly at-risk groups have not been well defined across youth Rugby. Furthermore, the lack of consistency in methodological approaches taken by different epidemiological studies of youth Rugby make comparisons between different rugby studies and of rugby injury data with other youth sports challenging.

Following on from epidemiological investigations, understanding the role of potentially modifiable risk factors for injury causation is a necessary pre-requisite to developing appropriate interventions. Currently, very little information regarding key risk factors for youth rugby injury is available. Match play across youth and adult Rugby is invariably characterised by frequent player-to-player contact events incorporated within intermittent bouts of high intensity activity, even though the playing laws and match durations vary throughout the younger age groups in comparison with the adult game (Duthie, Pyne, & Hooper, 2003; Duthie, Pyne, Marsh, & Hooper, 2006; Roberts, Trewartha, Higgitt, El-Abd, & Stokes, 2008). As such, players must develop a multitude of physical characteristics (strength, power, speed, agility, and endurance) in order to compete safely and effectively for rugby. The roles of anthropometry and physical capability in rugby players have been widely described in relation to understanding how they associate with playing demands of rugby and player selection policies, with the view to optimising training prescription and talent selection of players. However, their roles as injury risk factors are presently unclear.

There are a variety of interventions that may be used to prevent sports injuries. In Rugby, manipulating the laws surrounding scrum engagement protocols, enhancing coach and referee practice to improve technical and physical aspects of playing and training standards, and advocating the use protective equipment (e.g. mouth guards) are all examples of attempts made to reduce injury risk for players. Many of these initiatives focus on reducing the injury risk attached to contact playing events such as the tackle and scrum and traumatic injuries to the head and cervical spine that

threaten the subsequent quality of life of injured players and the public profile of the sport. However, few attempts have been made to reduce the risk of less severe although more frequent musculoskeletal injuries. Emerging evidence from other youth sports has begun to promote the use of pre-activity preventive exercise regimens to reduce the risk of soft-tissue injuries. Although predominantly developed for use with female participants, recent work has suggested that similar programmes are also useful in preventing injuries in male participants. Whether these programmes would also be of use in reducing injury risk within a more contact-orientated sport is largely unknown, however.

This thesis investigates the injury risk factors and evaluates novel injury prevention efforts within youth Rugby, with a view to informing and optimising the formulation and delivery of subsequent injury prevention strategies within the sport. The results of this programme of work may be of interest to a number of stakeholder groups in ensuring that rugby participation and performance remains enjoyable, inclusive, and sustainable; and players have the opportunity to enhance their health and sporting ability without an unnecessarily high risk of injury. Findings from this work may aid subsequent efforts to develop preventive strategies through the identification of relevant modifiable injury risk factors. Finally, evidence for the efficacy of a preventive measure in a controlled setting is a crucial precursor to directing real-world implementation efforts. Work from the final chapters of this thesis will therefore provide a platform from which subsequent research efforts can begin to implement a preventive exercise programme for youth rugby into more ecological settings to assess effectiveness.

The following research questions will be addressed:

i.   Are selected anthropometric, and physical fitness characteristics associated with injury incidence in youth rugby players?

ii.   Can a pre-activity movement control training programme reduce injury outcome measures during 12 weeks of use, when compared with a standardised control exercise programme in youth rugby players?

iii.   Is the weekly dose (frequency of completion) of a movement control
        training programme associated with injury outcome measures during 12
        weeks of use in youth rugby players?

iv.   Is compliance with using a movement control training programme
        (proportion of all possible programme parts completed) associated with
        injury outcome measures during 12 weeks of use, when compared with a
        standardised control exercise programme in youth rugby players?

v.   Are coach-related psychosocial factors related to compliance with using a
        movement control or standardised control exercise programme in youth
        rugby?

1.2   Thesis Outline

1.2.1   Chapter Two: A Review of the Literature

Chapter Two provides a contextual background for the subsequent experimental
chapters of this thesis by referring to existing literature in injury epidemiology and
injury prevention within Rugby. Objectives here are to outline the impact and nature
of injury, injury causation, and existing injury prevention measures with a primary
focus on youth Rugby.

1.2.2   Chapter Three: The influence of selected Anthropometric and Physical
             Fitness Characteristics on Injury Risk in Schoolboy Rugby Players

The aim of Chapter Three is to determine the associations between several selected
anthropometric and physical fitness-related characteristics and injury risk in youth
rugby, to understand more about potentially modifiable intrinsic risk factors for
injury within youth Rugby.

1.2.3   Chapter Four: Exploring the process of developing a Preventive Exercise Programme for use in Schoolboy Rugby Union

Chapter Four presents a narrative piece that outlines and critically assesses the steps taken to formulate and implement a preventive movement control exercise programme to reduce injury risk in a youth Rugby population. Emphasis is given towards the steps that are necessary to create the structure and content of the exercise programme, and to consideration of the delivery strategy, study setting and study design that are employed to assess the efficacy of the exercise programme.

1.2.4   Chapter Five: the efficacy of a pre-activity Movement Control Exercise Programme to reduce injuries in Schoolboy Rugby Union: a cluster randomised controlled trial

Chapter Five assesses the efficacy of a movement control exercise programme, when compared with a standardised exercise programme, to reduce outcome measures associated with injury in a cohort of youth rugby players. Evidence of this nature is a crucial first step in being able to translate and assess the effectiveness of this programme in real-world environments. Additional aims included exploring the influence of exercise programme dose and compliance on injury risk.

1.2.5   Chapter Six: The association between psychosocial factors and compliance with a Movement Control Exercise Programme amongst School rugby coaches

Chapter Six investigates the nature of coach-related psychosocial factors whether these factors are related to compliance with delivering a movement control or standardised control exercise programme with their players. Understanding the nature of coach behavioural profile and its influence on compliance in this setting is important for informing future programme design and delivery strategy within this population.

1.2.6   Chapter Seven: General Discussion

Chapter Seven synthesises the key findings from each chapter and summarises the main findings of this thesis. The potential for translation of the research findings into practice and the generalisability of this research approach into other settings are evaluated. Finally, the potential directions for future research based on the present investigations within this thesis are discussed.

CHAPTER TWO

A Review of the Literature

2.1   Overview

This chapter aims to appraise the literature that characterises the epidemiology of injury in youth Rugby. In doing so, this Chapter will provide a rationale for the current programme of research and a contextual basis in which findings of the subsequent experimental chapters in this thesis can be regarded. Specifically, this chapter will address the nature and impact, causation, and prevention of Rugby-related injuries, as well as the behavioural influences of preventing sports injuries in general. Literature pertaining to the use of preventive exercise programmes for sports injury prevention will be reviewed as part of Chapter 4 (see section *4.2*) and so will not be directly addressed in this Chapter.

2.2   Sports Injury Research

Sports injury research is underpinned the principles of epidemiology, an aspect of modern medicine which focuses on the spread of and defining factors behind health states, such as disease and infirmity, in human populations (Micheli, 2010). Under this paradigm, sports injuries are not a result of chance occurrences but instead are a potential outcome of the interplay between certain intrinsic and extrinsic factors (Gordon, 1949). The principal goal of epidemiological research is to reduce the risk or burden of injury or disease through targeted and evidence-informed interventions, which are the result of studying the injury patterns and inciting factors for injury within defined populations.

Employing frameworks that are uniformly accepted in sports injury research permits comparability between research findings across diverse fields, as well as identifying gaps in existing literature and how study findings can contribute to furthering the broader research area. *Section 2.2* provides a summary of the conceptual models used in the literature in relation to sports injury epidemiology and prevention.

2.2.1   The Sequence of Prevention

The most well-known framework for sports injury research is the sequence of prevention conceptualised by van Mechelen and colleagues (1992), which was adapted from an existing public health prevention model (Robertson, 1992). This 4-stage model (Figure 2.1) proposed that the magnitude of the injury problem in a population must first be described through injury outcome measures of frequency and severity (stage 1), before identifying the underlying factors and mechanisms that contribute to injury occurrence (stage 2). Stage 3 introduces preventive measures with the aim of reducing injury outcomes, before stage 4 evaluates the effect of preventive measures by repeating stage 1.
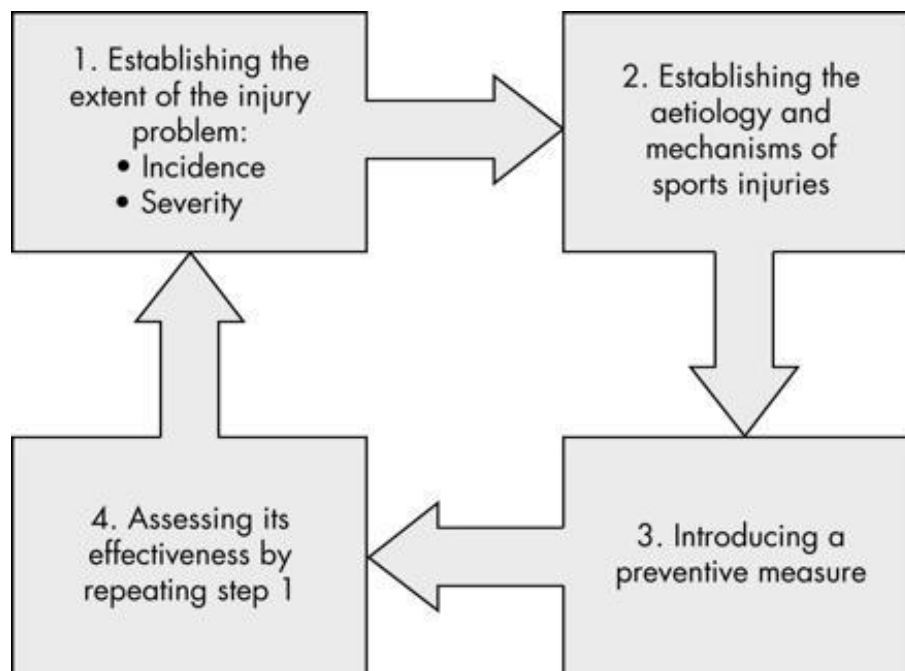
Figure 2.1   The Sequence of Prevention Model (Van Mechelen et al., 1992)

2.2.2   A Risk Management Framework for Sports-related Injuries

Proposed by Fuller and Drawer (2004), the risk management in sport framework takes an organisational approach towards injury prevention (Figure 2.2). The first stage of the framework addresses the identification of injury risk factors through epidemiological research. Subsequently, the framework attends to the perceptions of injury risk and levels of risk acceptance amongst stakeholders as an intermediary

step to deciding if there is a need to introduce preventive strategies (Fuller, 2007). Following the implementation of preventive measures and reduction of injury risk to socially acceptable levels, the fourth stage of the framework highlights the need to communicate information to stakeholders around the risk of injury and the measures available to control injury risk (Fuller, 2007). The risk management framework encompasses the same theoretical principles of injury epidemiology, causality and prevention as the Sequence of Injury Prevention model, but also extends to additional factors such as risk evaluation, perception, and communication of information to stakeholders.
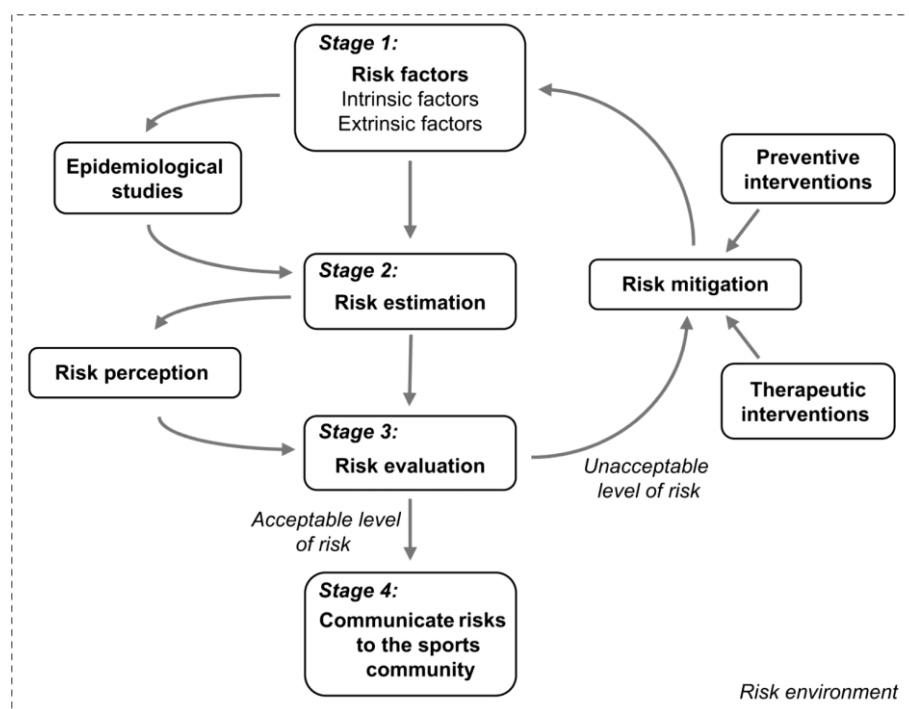
Figure 2.2   Injury Risk Management in Sport (Fuller & Drawer, 2004)

2.2.3   *The Translating Research into Injury Prevention Practice (TRIPP) Framework*

Once the efficacy of a preventive intervention has been demonstrated in a controlled setting, there is a need to translate the intervention to impact public health in real world settings. The Sequence of Injury Prevention and Risk Management

frameworks are both limited in being able to explain the behavioural factors which contribute to the acceptance and uptake of interventions. The TRIPP model, developed by Finch (2006), extended the sequence of prevention beyond determining efficacy and towards understanding the wider context into which interventions will be implemented, and which factors could facilitate or impede adoption and use in these contexts (Figure 2.3). The key premise of this extension was that determining the efficacy of a preventive strategy under controlled settings would be insufficient to prevent injury in the real world, where preventive interventions would only be impactful if readily and widely adopted and maintained (Hanson, Allegrante, Sleet, & Finch, 2014).
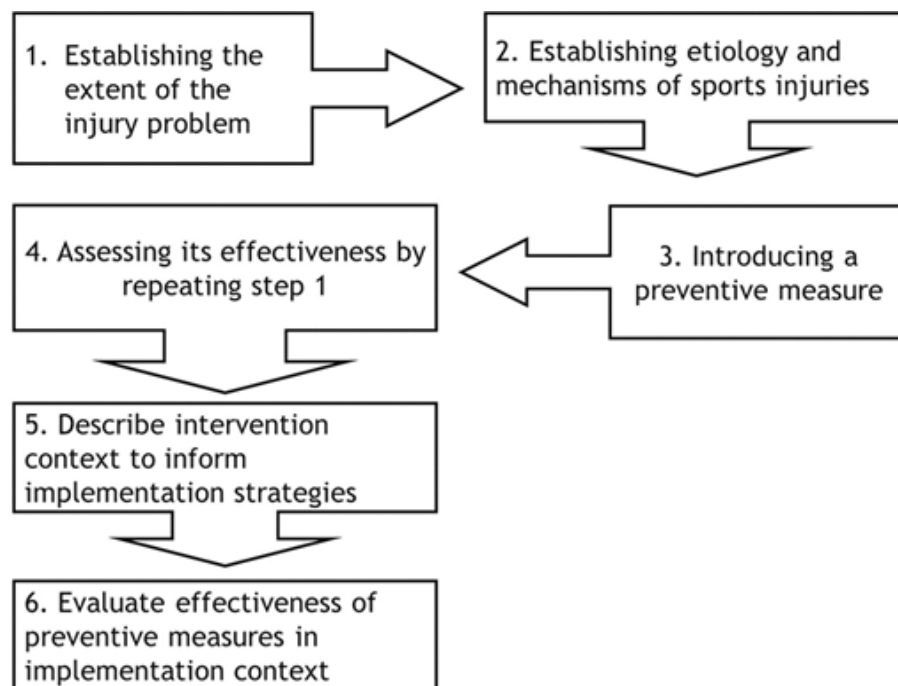
Figure 2.3   The TRIPP Model (Finch, 2006)

Across these models, research conducted in the early stages is invariably cast as descriptive injury epidemiology of a specific sport, population, and/or injury type. Descriptive epidemiology has been the predominant type of epidemiological research published in the literature (Micheli, 2010), highlighting that research attempts have largely yet to move beyond the initial stages of these models in many settings (Chalmers, 2002). The latter stages of the research frameworks are characterised by analytical epidemiology research (i.e., risk factor identification) and intervention studies, which often requires additional resources, more complex study

designs, and encounters greater logistical and administrative challenges in comparison with descriptive epidemiological studies (Micheli, 2010). It is possibly for these reasons that the volume of analytical epidemiology research has been limited when compared with descriptive epidemiology research. Klügl et al. (2010) highlighted a discrepancy when reviewing studies pertaining to sports injury epidemiology and prevention, indicating that there was a ratio of almost three descriptive epidemiological studies for each intervention study in the published literature. Furthermore, many of the intervention articles were devoted to training or equipment-based intervention measures, with regulation-based interventions underrepresented. This conclusion was upheld in a review by McBain et al. (2012b), which identified a similar distribution favouring protective equipment and training-based interventions, but fewer studies concerned with regulation or education-based preventive measures.

2.3 Establishing the extent of the injury problem

2.3.1 Impact of Sports Injuries

Sports-related injuries are a common form of non-fatal injury and a prominent reason for physical impairment (Michaud, Renaud, & Narring, 2001; Schneider, Seither, Tönges, & Schmitt, 2006). Whilst the immediate absence from sport or physical activity is the most commonly acknowledged drawback of sports-related injuries, there can be other considerable consequences for stakeholders (Van Mechelen, 1997). This section details the different mechanisms through which injuries can impact stakeholders involved in youth sport.

2.3.1.1 Long-term Player Health

Many sports-related injuries are relatively minor, and athletes will return to full participation without complication (Kujala, Orava, Parkkari, Kaprio, & Sarna, 2003). However, some injuries can result in irreversible damage with subsequent long-term physical complaints or health problems. The tolerance of the immature skeletal system to mechanical forces and repetitive loading is an important consideration for young athletes, particularly across sports with frequent exposure to repetitive high intensity events (Caine, DiFiori, & Maffulli, 2006). The epiphyseal growth plates

(physes) are susceptible to damage during periods of rapid growth (Adirim & Cheng, 2003), with physeal injuries causing limb length discrepancies, angular deformities, altered joint mechanics, and disability in extreme cases (Caine et al., 2006). Moreover, there is a strong association between joint injury and premature development of osteoarthritis in the lower limb, such that at least half of young athletes that sustain a significant anterior cruciate ligament (ACL) and/or meniscal injury are estimated to develop knee osteoarthritis with associated pain and functional decrements within 10 to 20 years of the initial injury (Lohmander, Englund, Dahl, & Roos, 2007). A study conducted in male former elite athletes confirmed that soccer, handball, and ice hockey players were significantly more likely to develop hip and knee osteoarthritis (adjusted odds ratio=1.72-2.05) and require hip or knee arthroplasty (adjusted odds ratio=2.72-3.35) than matched controls (Tveit, Rosengren, Nilsson, & Karlsson, 2012). Results of this study highlight that athletes involved contact sports may be at particular risk of developing secondary health complications such as osteoarthritis (Tveit et al., 2012).

From adolescence onwards, participating in full contact sports such as Rugby entail a risk of permanently disabling (catastrophic) head and spinal cord injuries (Brown et al., 2013; Fuller, 2008; Quarrie, Cantu, & Chalmers, 2002). While catastrophic injury types are rare, they can lead to lifelong morbidity, severely compromised quality of life, and incur extensive medical care costs (Quarrie et al., 2002). The cumulative impact of playing Rugby is also thought to accelerate long-term spinal degeneration amongst players (Berge, Marque, Vital, Sénégas, & Caillé, 1999; Castinel et al., 2010; Scher, 1990; Swaminathan, Williams, Jones, & Theobald, 2016). Spinal abnormalities have primarily been associated with an extensive history of playing Rugby amongst adult players, but a study in adolescent Rugby revealed that 74% of 327 players had at least one radiographic lumbar spine abnormality (i.e. spondylolysis, vertebral disc stenosis, spinal instability) (Iwamoto, Abe, Tsukimura, & Wakano, 2005). The same study also identified that players with lumbar spine spondylolysis were significantly more likely to report low back pain than counterparts with no evident radiographic spinal defects (Odds Ratio=3.03) (Iwamoto et al., 2005), suggesting that the loading patterns inherent in Rugby could be linked to spinal abnormalities that manifest in pain or dysfunction amongst young players (Kujala et al., 2003).

Repeated exposure to head impacts and concussion has been a principal concern for full-contact sports globally, with recent evidence pointing to the effect of concussion history on neurocognitive decrements (Hume et al., 2016), and the risk of suffering from neurodegenerative disease amongst former contact sport athletes (Gardner, Iverson, & McCrory, 2014; Maroon et al., 2015). Younger athletes are acknowledged to be particularly susceptible to concussion and to take longer to recover than their older counterparts (Purcell, 2009). Moreover, the neurocognitive symptoms associated with concussion may persist after other clinical symptoms have resolved, and there is a suggestion that a history of suffering multiple concussions may adversely affect neuropsychological function and academic performance amongst adolescent contact sport athletes (Brosseau-Lachaine, Gagnon, Forget, & Faubert, 2008; Moser, Schatz, & Jordan, 2005).

2.3.1.2 Financial Costs

There are likely to be various financial costs associated with injury, and examining financial costs can be useful in highlighting injury types that are associated with high financial burden so to direct limited resources towards preventing these injuries. Only a few financial cost evaluations of sports-related injuries have been conducted in youth sports (Brown et al., 2015; Collard, Verhagen, Van Mechelen, Heymans, & Chinapaw, 2011; Knowles et al., 2007), but the few studies that have been conducted suggest that injuries associated with participating in contact sports appear to incur the greatest financial costs. A study in high school athletes from several different sports noted that injuries sustained in wrestling (670 US$ per injury) and American football (577 US$ per injury) incurred the greatest medical costs compared with basketball ($401 per injury) and volleyball ($322 per injury) (Knowles et al., 2007). Similar trends were also found when costs accounted for lost future earnings and value of good health lost due to injury (Knowles et al., 2007). The only study to be conducted in a youth Rugby population to-date identified similarly high mean costs of follow-up medical treatment (731 US$ per injury) (Brown et al., 2015). A possible reason for the relatively high medical costs of injuries sustained in contact sports may include the relatively high proportion of severe injury types sustained by athletes in these sports. Severe injuries may not only incur substantial costs for

immediate treatment, but also through prolonged rehabilitation or time away from work / education.

Sources of financial costs for injury may be grouped into two categories. Direct costs relate to the treatment and rehabilitation of an injury, whilst indirect costs cover time away from work / education to be treated or make other arrangements such as childcare (Collard et al., 2011). Studies have typically tended to report direct healthcare costs, whilst fewer have reported indirect healthcare costs. The lack of indirect healthcare costs to-date may be important, as a study by Abernethy and MacAuley (2003) showed that almost one in three parents (32%) needed to take time away from work to take their children to receive treatment for sport-related injuries. That said, a study in schoolchildren that addressed both direct and indirect sources of financial cost showed direct healthcare costs to be greater in comparison with indirect sources (Collard et al., 2011)

2.3.1.3 Public Profile of Sport

Regular engagement in physical activity is universally accepted as a means of reducing non-communicable disease-related morbidity and mortality, as well as improving fitness, health and social well-being across the life span (Allender, Cowburn, & Foster, 2006; Lee et al., 2010). Participation in organised sports is a primary source of physical activity engagement amongst youth populations (ages 6-14 years) (Michaud et al., 2001; Sallis, Prochaska, & Taylor, 2000), and may constitute between 23-55% of overall moderate-to-vigorous physical activity depending on the sporting activity (Katzmarzyk & Malina, 1998; Leek et al., 2011; Wickel & Eisenmann, 2007). Given the numerous short- and long-term benefits of engaging in physical activity that can be conferred during childhood and carried into adulthood if maintained (Boreham & Riddoch, 2001; Telama et al., 2005), promoting sports participation to young people may be an important step in raising global physical activity levels amongst this demographic (Mountjoy et al., 2011). However, injuries can be a barrier to sports participation (Finch, Owen, & Price, 2001), whilst concerns over injury risk may discourage childhood sports participation (Boufous, Finch, & Bauman, 2004; Telford, Finch, Barnett, Abbott, & Salmon, 2012). Therefore, injury risk presents an obstacle which must be balanced

against positive health-based outcomes when participating in sport (Finch & Owen, 2001). In cases where players or guardians perceive that the risk of injury outweighs the positive outcomes associated with participation in a given sport, they may be more likely to seek perceived lower-risk alternatives.

Given their potential to effect change, sporting organisations have a responsibility to investigate ways to reduce injury risk (Emery, Hagel, & Morrongiello, 2006). Risk assessments are a legal requirement across occupational settings in the United Kingdom, with work-related activities assessed against established metrics for what constitutes an acceptable level of risk to employees (Health and Safety Executive, 2000). However, injuries arising from sports participation across community settings are not covered by existing UK Health and Safety Executive legislation, and frameworks for deducing what constitutes an acceptable level of risk in sport are lacking (Fuller & Drawer, 2004). In cases where information has not been adequately collected or communicated, this may leave the possibility that subjective evaluations of injury risk, rather than objective quantification, will become the primary determinant of risk perception (Fuller, 2007). Ultimately, the popularity of certain sports may suffer if societal perceptions are that the injury risks are excessively high when measured against the benefits of participation.

2.3.1.4 Summary

This section has highlighted that there are several health-related, financial, and social reasons why injury surveillance and prevention research should be a research priority across contact sport settings. Certain injury types may be associated with long-term health sequelae amongst youth contact sport athletes, although further research is needed to identify the prospective health consequences of spinal abnormalities and head impacts in this population. There is also evidence that points to potentially high financial costs of medical treatment amongst youth athletes, although it is unclear at present how these costs correspond with indirect costs. Sports that can demonstrate an appropriate balance between desired participation outcomes and adverse consequences will be likely to benefit from a favourable public profile. However, there are currently no formal criteria to determine the acceptability of injury risk at community and youth playing levels. These issues stress the need to adopt an

evidence-based approach to injury epidemiology and prevention across sport, and to communicate injury risk information and preventive measures to stakeholders.

2.3.2   Injury Epidemiology in Rugby Union

Given the physically intense, contact-orientated nature of match play, injury incidence rates across many playing levels of Rugby are understandably high when viewed against comparable playing levels in many other team sports (Brooks & Kemp, 2008). Most of the epidemiological research within Rugby to date has been undertaken at senior elite playing levels, with injury patterns at this playing level now well-described with appropriate and consistent methodological approaches (Williams, Trewartha, Kemp, & Stokes, 2013). This allowed Williams et al. (2013) to conduct a meta-analysis of injury patterns across senior professional men's Rugby, with pooled estimates indicating an overall match injury incidence rate of 81 injuries/1000 player-match-hours (95% CL 63-105) and a mean severity of 20 days for match injuries (95% CL 14-27).

In comparison with elite playing levels, epidemiological studies in sub-elite youth Rugby have encountered considerably greater variability in study settings, sample demographics, and data collection procedures (Freitag et al., 2015b). A recent meta-analysis of injury patterns across Rugby and Rugby League (a similar football code) in children and adolescent players (aged <21 years) identified 35 relevant studies, most of which were prospective cohort studies conducted in teams over the course of playing seasons or tournaments, but also included hospital-based injury surveillance systems and retrospective studies conducted via surveys and questionnaires to players. The varying data sources across these included studies were highly likely to impact on the choice of injury definition and use of exposure data in calculating incidence rates. Only eight of the thirty-five studies adhered to the definition of a reportable injury given by the consensus statement for data collection procedures in Rugby-related epidemiological research (Fuller et al., 2007b). A combination of *time-loss* injuries (subsequent time-loss greater than 24 hours or 7 days, missed match or training, etc.), *medical attention* injuries, and attendance at hospital facilities were evident in the remainder of studies. This variation in injury definition explains the similarly variable incidence rates that have been recorded. For instance,

the widest range of injury incidence have been seen in studies that adopted a *medical attention* definition (19 injuries/1000 player-hours to 130 injuries/1000 player-hours) (Junge, Cheung, Edwards, & Dvorak, 2004b; Rotem & Davidson, 2001), whilst studies incorporating *time-loss* injury definitions have returned a lower and narrower range of injury incidence rates (greater than 24 hour time-loss: 12/1000 player-hours to 47/1000 player-hours; missed match/training: 11/1000 player-hours to 48/1000 player-hours (Haseler, Carmont, & England, 2010; Nicol, Pollock, Kirkwood, Parekh, & Robson, 2011; Palmer-Green et al., 2013; Takemura et al., 2009). Furthermore, nineteen studies reported injuries per 1000 player-hours, whilst a combination of injuries per 100 or per 1000 player-matches or practices, per 1000 athletic exposures, and per 1000 player-seasons were also observed (Freitag et al., 2015b).

The inter-study variation evident across youth Rugby injury epidemiology research may be related to the relatively high proportion of studies that were conducted before the introduction of a consensus statement, which sought to harmonise working definitions and data collection procedures in Rugby (Fuller et al., 2007b). Only nine of twenty-two studies included in the pooled estimate of match injury incidence in the meta-analysis were published post-consensus statement, of which five adhered to the consensus definition of injury and seven recorded injury incidence as injuries per 1000 player-hours (Freitag et al., 2015b). This would support that inter-study variation in outcome reporting has narrowed post-consensus as more studies have adhered to the guidance given.

Freitag and colleagues' meta-analysis (2015b) revealed an overall match injury incidence rate of 27 injuries/1000 player-hours (95% CL 13-54) in youth Rugby, irrespective of injury definition. This figure is greater than match (game) injury incidence values in youth ice hockey (9/1000 player-hours – *medical attention* / *time-loss* injury definition applied) (Emery & Meeuwisse, 2006) and soccer (16/1000 player-hours – *time-loss* injury definition applied) (Junge, Cheung, Edwards, & Dvorak, 2004a), but noticeably lower than injury incidences in youth Australian Rules Football (77/1000 player-hours – *medical attention* definition applied) (Romiti, Finch, & Gabbe, 2008), and high school American Football (84/1000 player-hours – *medical attention* / *time-loss* injury definition applied) (Meyers &

Barnhill, 2004). Moreover, the pooled estimate from youth Rugby is one-third of that which was calculated in professional Rugby (Williams et al., 2013), whilst the pooled incidence of (>7 days) time-loss injury (10/1000 player-hours) was slightly lower than seen in adult sub-elite Rugby (17/1000 player-hours) (Roberts, Trewartha, England, Shaddick, & Stokes, 2013). Note, the pooled incidence provided by Freitag et al. (2015b) encapsulated injury rates for players aged 6-21 years inclusively and did not account for the distribution of age groups researched within the included studies via sub-group analysis or weighting of studies. The use of pooled data here may be misleading, given the association between age and injury in Rugby (see *section 2.4.5.1*), and may mask individual differences in injury rate between age groups (Tucker, Raftery, & Verhagen, 2016).

Match injury severity in youth Rugby (expressed as a mean number of days lost) has been reported to be between 22-33 days lost (Archbold et al., 2015; Fuller & Molloy, 2011; Haseler et al., 2010; Palmer-Green et al., 2013). When categorised by severity, *minimal* injuries (2-3 days) may account for 28% of match injuries, *mild* injuries (4-7 days) 24%, *moderate* injuries (8-28 days lost) 21-41%, and *severe* injuries (>28 days lost) 22-49% (Archbold et al., 2015; Fuller & Molloy, 2011; Haseler et al., 2010; Palmer-Green et al., 2013). The mean severity of injuries displayed here corresponds with the mean estimate of 20 days lost (95% CL 14-27 days) for professional players calculated by Williams et al. (2013), whilst *moderate* injuries were also found to be the most common severity classification at elite playing levels, followed *mild*, *minimal*, and *severe* injuries.

The lower limb has been shown to be the most frequently injured body location in youth Rugby players, accounting for 24-55% of all match injuries, followed by the upper limb (24-31%), head/neck region (14-41%), and trunk (3-10%) (Archbold et al., 2015; Fuller & Molloy, 2011; Haseler et al., 2010; Leung, Smith, & Hides, 2017; Leung, Franettovich Smith, & Hides, 2016; Palmer-Green et al., 2013). Amongst these categories, the head/face, shoulder, knee, and ankle appear to be the most commonly injured specific locations (Archbold et al., 2015; Collins, Micheli, Yard, & Comstock, 2008). Additionally, joint (non-bone) and ligament injuries are commonly reported injury types amongst youth Rugby players (15-51%), followed by musculotendinous injuries (9-39%), concussion (16-21%), bone fractures (6-

17%), and lacerations/contusions (3-26%) (Archbold et al., 2015; Collins et al., 2008; Fuller & Molloy, 2011; Haseler et al., 2010; Leung et al., 2017; Leung et al., 2016; Palmer-Green et al., 2013). Of note, the knee and shoulder joints have been shown to be at a particularly high risk of severe injuries, such as ligament injuries (sprains), fractures, dislocations, and muscle injuries (strains), whilst hand/finger fractures and concussion have also been identified as injury types associated with a high burden in youth Rugby players (Archbold et al., 2015; Collins et al., 2008; Palmer-Green et al., 2013).

2.3.3   Summary

This section has highlighted that injury incidence rates in youth Rugby may be high when compared with other youth sports, comparable with similar youth full contact sports such as the Australian and American football codes, and lower when viewed against adult sub-elite and elite Rugby playing populations. Although methodological approaches in epidemiological studies in youth Rugby have improved in recent years, a dearth of research remains in this population, with no longitudinal datasets that permit the assessment of changing risk factors or trends in injury patterns over time. Based on existing evidence, lower and upper limb injuries (specifically knee and shoulder joint injuries) and concussion should be priority injury types to be prevented amongst youth players.

2.4   Establishing the Aetiological Basis for Injury

The second stage of the Sequence of Injury Prevention and TRIPP models specify that sports injury research should aim to identify why particular individuals may be at an increased risk of injury in certain situations, and how injuries occur (Bahr & Holme, 2003). In the same way that the above models have been useful in guiding research efforts across sports injury epidemiology, so similar models have furthered understanding of the causal pathway from which injuries are thought to occur.

2.4.1   Multifactorial Model of Injury Aetiology

Meeuwisse (1994) provided the first model to address the complex, multifactorial nature of sport injury. In doing so, the Multifactorial Model of Injury Aetiology facilitated the assessment of multiple risk factors and inciting events that are

characterised as part of the sequence of events that lead to injury. To begin with, intrinsic risk factors (e.g., age, previous injury, gender) are thought to predispose an individual to injury, whereupon subsequent exposure to extrinsic risk factors (e.g., playing environment, conditions, equipment) render the individual susceptible to injury. Both intrinsic and extrinsic risk factors are considered to be necessary but not sufficient for injury to occur. An 'inciting event' is required to cause an injury (e.g., contact with another player or the ground, rapid change of direction), which is typically associated directly with injury onset in the case of acute injuries but may be less obvious for gradual onset injuries.

2.4.2   A Cyclical, Operational Model to investigate Contact Sport Injuries

The Multifactorial Model of Injury Aetiology has been found to be limited in its ability to account for the time-varying influence of risk factors in response to the recursive nature of exposure, injury, and return to sport. Specifically, Gissane, White, Kerr, and Jennings (2001) posited that the premise of the Multifactorial Model of Injury Aetiology as a linear model with defined start (healthy individual) and end-points (injury) may be overly simplistic in addressing the causal pathway to sports injury. The authors (Gissane et al., 2001) subsequently proposed a Cyclical Operational Model (Figure 2.4), which similarly begins with a healthy/fit individual within which a number of intrinsic risk factors exist. With exposure to external risk factors and potential injury events, individuals will either repeat exposures if they remain uninjured or progress to the injured state if they do sustain an injury. Once an injury has been sustained, the injured individual will subsequently undergo treatment and rehabilitation with the aim of returning to their pre-injury state and playing level, although other potential outcomes include retirement from sport, injury recurrence, or returning to sport at a lower level than prior to the injury.
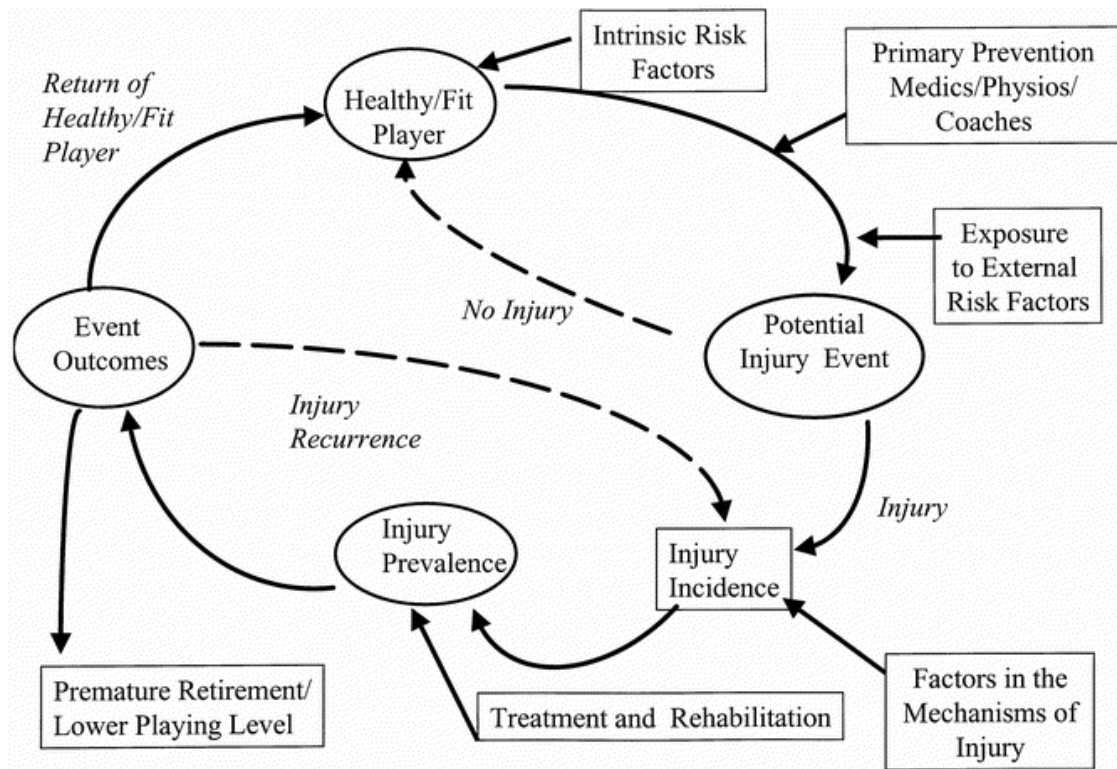
Figure 2.4   A Cyclical Operational Model to investigate contact sport injuries (Gissane et al., 2001)

2.4.3   A Dynamic, Recursive Model of Aetiology in Sport Injury

Following the Cyclical Operational Model, Meeuwisse, Tyreman, Hagel, and Emery (2007) contended that existing frameworks did not stress that susceptibility to injury changes recurrently with repeated participation due to adaptations or maladaptations (e.g., biomechanical, physiological, etc.). Meeuwisse et al. (2007) subsequently proposed the Dynamic, Recursive Model of Aetiology (Figure 2.5). The premise of this model was based on repetitive exposures altering the influence of intrinsic risk factors independently of injury, thereby influencing the susceptibility to injury in subsequent exposures. Similarly to the Cyclical Operational Model, injuries lead to treatment and rehabilitation before returning to participation or retiring. Once individuals recover from injury, the previous injury may alter the make-up of intrinsic and extrinsic risk factors that influence injury risk during subsequent exposures.
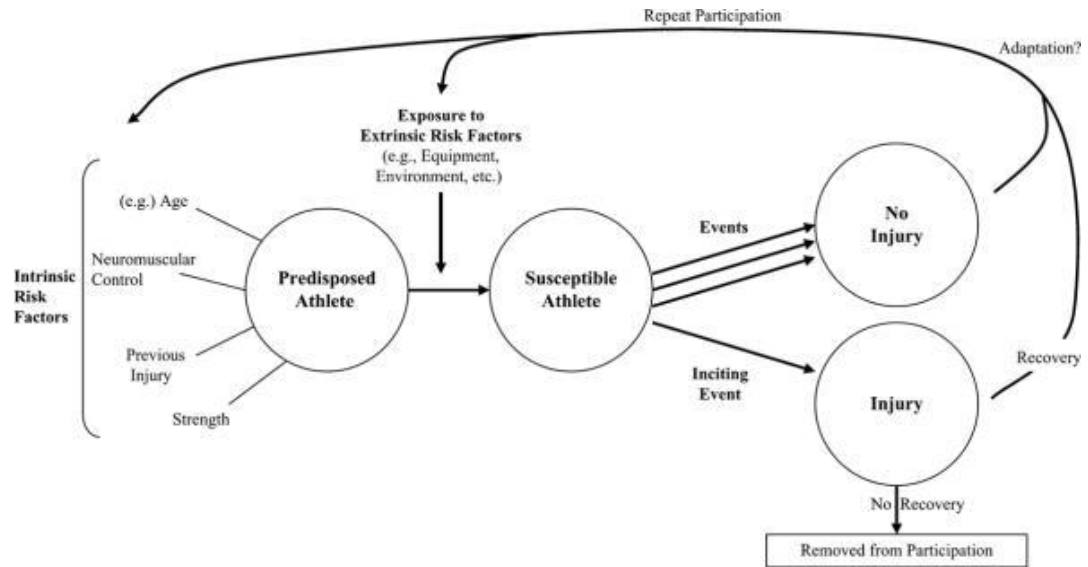
Figure 2.5   A Dynamic, Recursive Model of Aetiology in Sport Injury
(Meeuwisse et al., 2007)

2.4.4   Summary

Injury causation represents a complex aspect of sports injury research, with several models developed to address the interaction between injury risk factors and inciting events. These models have been useful in shaping study designs and analysis of the associations between prospective risk factors and injury risk, with the most recent model citing the need to account for the effect of repetitive exposures and injury on the make-up of risk factors that influence injury risk.

2.4.5   Injury Risk Factors and Inciting Events in Rugby Union

2.4.5.1 Intrinsic Risk Factors

2.4.5.1.1   Age

Although non-modifiable, age is one of the most straightforward risk factors to assess and can be used to identify at-risk subgroups within a population. Evidence relating to the effect of age as an injury risk factor in Rugby remains equivocal. An initial study in Scottish community Rugby identified that players aged 25-29 years

were at three-times greater risk of injury when compared with players aged younger than 16 years, albeit without accounting for confounding factors (Lee & Garraway, 1996). This finding was not upheld by a study in New Zealand community Rugby players, which showed that the association between age and injury risk between youth and adult age groups was not sustained following multivariate adjustment for other risk factors such as playing level and previous injury history (Quarrie et al., 2001). More recently, research conducted in a similar demographic of New Zealand community Rugby players did identify an association between increasing injury risk from 13-15 year-olds to >35 year-old players after adjusting for other significant risk factors (Chalmers, Samaranayaka, Gulliver, & McNoe, 2012). The increased risk in adult Rugby compared with youth playing levels may be the result of differences in the general physical demands of match-play (Austin, Gabbett, & Jenkins, 2011; Read et al., 2017; Roberts et al., 2008), greater mechanical forces expressed during contact events such as the tackle situation (Hendricks, Karpul, & Lambert, 2014; Hendricks, Karpul, Nicolls, & Lambert, 2012), or enhanced physical characteristics amongst players (Delahunt et al., 2013; Fuller, Taylor, Brooks, & Kemp, 2013). The increased injury risk in adults relative to youth players also highlights the possibility that prolonged and repetitive exposure to mechanical loads may reduce to the musculoskeletal system's load-bearing capacity, such that normal biomechanical loads become injurious (Kumar, 2001).

Evidence from several studies conducted specifically within youth Rugby support that injury rates increase as a function of age group, irrespective of study settings and methodological issues such as injury definition (Brown et al., 2012; Lee & Garraway, 1996; Leung et al., 2017; Leung et al., 2016; McIntosh, McCrory, Finch, & Wolfe, 2010; Roux & Goedeke, 1987). A study by Haseler et al. (2010) revealed that match injury incidence increased by 5/1000 player-hours (95% CL 4-7) per age group on average between under-10 and under-17 age groups. Findings from other epidemiological studies suggest that there may be a 'break point' during mid-adolescence (ages 13-15 years) following which injury incidence rates increase. Leung et al. (2017) identified sharp increases in head/face, upper limb, and lower limb injuries in under-14, under-15, and under-16 players relative to under-13 players. The authors (Leung et al.) speculated that the reasons for this increase could be related to the varying effects of maturation on enhancing performance and

physical characteristics in players, as well as potential decrements in motor function (termed 'adolescent awkwardness') secondary to rapid growth spurts (Quatman-Yates, Quatman, Meszaros, Paterno, & Hewett, 2012). Although current evidence supports that older youth age groups (aged 14-18 years) are an at-risk sub-group within youth Rugby, few studies have assessed the effects of age as an injury risk factor in youth Rugby players when accounting for other factors. One of the only studies in youth Rugby to have investigated the role of age whilst accounting for other risk factors (body mass, playing level, injury history, strength profile) revealed that players aged older than 16.9 years were 45% more likely to be injured than players aged younger than 16.9 years (hazard ratio=1.45, 95% CL 1.14-1.83) (Archbold et al., 2015).

2.4.5.1.2   *Previous Injury*

Having previously suffered an injury is proposed to alter subsequent injury risk by influencing the make-up of intrinsic risk factors and contribution of extrinsic risk factors to injury susceptibility (Meeuwisse et al., 2007). Lee, Garraway, and Arneil (2001) identified that adult players that were carrying an injury at the conclusion of the previous season were at 61% greater risk of injury in the current season than players with no previous injuries (hazard ratio=1.61, 95% CL 1.32-1.97). Two studies conducted in sub-elite youth and adult Rugby recognised that players reporting either suffering an injury prior to the start of the current season (rate ratio=1.81, 95% CL 1.01-3.25) (Quarrie et al., 2001), or continuing to play whilst injured (rate ratio=1.46, 95% CL 1.20-1.79) were at a higher risk of subsequent injury than previously uninjured counterparts (Chalmers et al., 2012). These findings go some way to stressing the importance of undergoing adequate rehabilitation prior to returning from injury to reduce subsequent injury risk.

Archbold et al. (2015) identified that a history of any injury type was not associated with subsequent risk in adolescent Rugby players, but an interesting trend from this study was that players that reported sustaining a previous concussion were 26% more likely to sustain an injury compared with players that did not report suffering a previous concussion (hazard ratio=1.26, 95% CL 0.98-1.62). Similarly, two studies in sub-elite Rugby discovered the risk of concussion was 20-65% higher in players

reporting one or more concussions in the preceding 12 months compared with players with no history of previous concussion (Hollis et al., 2011; Hollis et al., 2009). In professional Rugby players, Cross, Kemp, Smith, Trewartha, and Stokes (2015b) described a 60% increase in subsequent injury risk amongst players returning from a concussion when compared with those that sustained other injuries (rate ratio=1.60, 95% CL 1.40-1.80). The underlying mechanisms for the relationship between past concussion and subsequent injury risk are unclear, although changes in neuromuscular control following concussion may be a consideration (Cross, Kemp, Smith, Trewartha, & Stokes, 2015a).

2.4.5.1.3   Ethnicity

Similarly to age, ethnicity is a non-modifiable factor, but assessment of the association with injury risk may allow at-risk subgroups to be identified. Studies have scarcely considered the role of ethnicity as an injury risk factor across Rugby. Two studies from community Rugby in New Zealand reported conflicting effects of ethnicity on injury risk. Quarrie et al. (2001) identified no difference in injury rates between players of Maori/Pacific Island origin or European origin, whilst Chalmers et al. (2012) revealed that Maori players were 48% more likely to suffer an injury than Pacific Island players (rate ratio=1.48, 95% CL 1.03-2.13). The underlying reasons for the latter finding are unclear, but are likely to be multifactorial and may include factors such as genetic predisposition, playing style, and anthropometric profile. Recently, a study conducted in sub-elite Rugby players in Australia noted differences in regional fat and lean body mass distribution between Caucasian and Polynesian players, with Polynesian players having a higher proportion of fat mass in their limbs and less in the trunk region than Caucasian players (Zemski, Slater, & Broad, 2015). High fat mass stores have been thought to provide a shock-absorbing barrier during contact situations in Rugby (Meir, 1993), which could explain why Polynesian players may have been at an increased injury risk compared with Caucasian players. In youth Rugby, a study conducted in elite under-18 players in South Africa identified significant differences in anthropometric profile between different racial sub-groups, with Caucasian players being 10-12 kg heavier and 7-8 cm taller than Black and Coloured players (Durandt, Green, Masimla, & Lambert, 2017). Such differences could influence individuals' injury risk, although at present

there have been no studies to investigate the interaction of ethnicity and anthropometric profile on injury risk in Rugby.

2.4.5.1.4 *Anthropometric Profile*

The physical size of Rugby players is a topic of interest, particularly as studies have shown that anthropometric characteristics may positively influence aspects of team performance (Barr, Newton, & Sheppard, 2014; Sedeaud et al., 2012). As a result, selection policies at elite senior and junior playing levels have indicated trends towards choosing taller and heavier individuals. On average, international players have been shown to be around 12 kg heavier and 4 cm taller following the advent of professionalism (Sedeaud, Vidalin, Tafflet, Marc, & Toussaint, 2013), whilst elite under-20 players have been shown to be 12 kg heavier and 5 cm taller on average from 1998 to 2010 (Lombard, Durandt, Masimla, Green, & Lambert, 2015), and elite under-18 players ~5 kg heavier and ~1 cm taller from 2002-2012 (Durandt et al., 2017). Training interventions can also shape anthropometric profile in players by increasing lean body mass, whilst conversely reducing fat mass to improve work-rate capacity and to tolerate the high physical demands associated with Rugby (Duthie, 2006; Smart, Hopkins, Quarrie, & Gill, 2011).

Lee, Myers, and Garraway (1997) investigated the effect of player physique as an injury risk factor in a sample of sub-elite Rugby players, and identified that players that went on to sustain an injury in match-play possessed a significantly greater Body Mass Index (BMI) than uninjured players after adjustment for age and playing position (25.4 vs. 24.6 kg.m^2). Similarly, Chalmers et al. (2012) identified an increased injury risk with greater height, body mass, and BMI amongst amateur Rugby players. In contrast, Quarrie et al. (2001) identified that greater BMI was associated with missing fewer weeks of the season due to injury following multivariate adjustment, which may support that heavier players were better capable of tolerating the physical demands of Rugby whilst lighter players were more likely to miss games due to injury.

Many of the studies to have assessed the role of anthropometric profile as an injury risk factor in Rugby have sampled across youth and adult sub-elite populations, which may mask or dilute the influence of anthropometry in youth players

specifically. Another pertinent consideration relates to the fact that that anthropometric characteristics may be more variable amongst youth players because of the effects of physical maturation. The results of several cross-sectional studies agree that height and body mass generally increase across elite youth Rugby age groups (Darrall-Jones, Jones, & Till, 2015, 2016; Durandt et al., 2009). In this context, Archbold et al. (2015) present one of the only studies to have assessed anthropometric profile in relation to injury risk in a specific population of adolescent Rugby players. Findings from this study revealed no effect of height on injury risk, but that players weighing more than 77 kg were 32% more likely to be injured than players weighing less than or equal to 77 kg (hazard ratio=1.32, 95% CL 1.04-1.69) after adjustment for other factors such as age and strength profile (Archbold et al., 2015). The increased injury risk for increasing body mass could relate to playing styles or tactical approaches that lead to heavier players being involved more frequently in contact events (Hendricks et al., 2014), or being capable of generating increased impact forces in contact situations (Hendricks et al., 2014; Quarrie & Hopkins, 2008).

Adolescent team sports are characterised by maturation-induced variations in growth rates, particularly during the period of peak height velocity. Wide variations in anthropometric profile can exist within the same youth age group bandings, which may contribute to injury in the case of sports involving player-to-player contact situations (Nutton et al., 2012). Of note, evidence is scarce for the role of player mismatches as an injury risk factor in youth contact sports such as Rugby. One of the few known studies to investigate the potential for physical mismatches in youth Rugby players found that developments in anthropometry and physiological fitness did not occur simultaneously in adolescent players (aged 11-15 years) (Krause et al., 2015). This study noted that that only 6% of 417 players were grouped in the highest age-specific tertiles for body mass, relative peak power, and linear sprint speed, whilst only 4% were classified in the lowest tertile for the same characteristics (Krause et al., 2015).

2.4.5.1.5   Components of Physiological Fitness

The diverse high intensity nature of Rugby means that all players must develop a base level of physiological fitness to participate both safely and effectively at a given playing level. At elite playing levels of Rugby, components of physiological fitness (aerobic capacity, speed, power, and strength) have been associated with favourable game behaviours (line breaks, distance covered, tackle breaks, work rate, tries scored, evading opposition players) (Smart et al., 2011; Swaby, Jones, & Comfort, 2016), thereby underlining the importance of enhancing physiological fitness in Rugby players. Additionally, developing physiological fitness may counter the effects of fatigue that arise from playing Rugby. Gabbett (2008; 2016) demonstrated that progressive fatigue led to decrements in tackle technique amongst Rugby League players, but that players with better agility, lower and upper body strength, and higher aerobic capacity were associated with less of a decrement in tackle technique under fatigue. In addition, Rugby League players with poorly developed high intensity intermittent running ability and upper body strength have been shown to be at an increased risk of contact injury, perhaps due to inferior tackle technique during match-play (Gabbett, Ullah, & Finch, 2012).

The role of physiological fitness as a risk factor has not been clearly identified in Rugby Union. In sub-elite Rugby players, Quarrie et al. (2001) identified no significant univariate associations between injury incidence and aerobic endurance (measured using a multistage shuttle run test), anaerobic endurance (measured using a high intensity shuttle run test), speed (measured using 30 m sprint time), lower limb power (measured using peak vertical jump height), or muscular endurance (measured via number of press-ups performed at a constant rate). However, multivariate analyses revealed that players with greater anaerobic capacity and upper body muscular endurance were almost three-to-four-times more likely to miss games due to injury than their counterparts (odds ratio= 2.73-4.42) (Quarrie et al., 2001). The latter of these findings could support that fitter players were able to cover a greater volume of activity during match-play, thereby increasing injury risk through more frequent exposure to certain match events (tackle / breakdown situations) that increased their risk of injury. Given that enhanced physiological fitness components (anaerobic capacity, strength) may be protective against injury in professional

Rugby, assessing whether similar characteristics may also influence injury risk in sub-elite settings bears the need for further research. In particular, the roles of speed and anaerobic capacity as risk factors for injury have not yet been investigated in youth Rugby players.

2.4.5.1.6 *Musculoskeletal Function*

As posited by the Cumulative Load Theory, repetitive and prolonged exposure to physical loads (without sufficient recovery) may effectively weaken the stress-bearing capacity of underlying tissues to the degree that normal physiological loads become injurious (Kumar, 2001). In light of this theory, weakened tissue structure and decreased function may be important contributors to injury. Herrington, Horsley, Whitaker, and Rolf (2008) demonstrated that repeated exposure to tackling adversely affected sensorimotor function at the glenohumeral joint in Rugby players, with the implication that decreased shoulder joint function could predispose to subsequent acute traumatic shoulder joint injuries because of joint instability, or gradual onset injuries through repetitive microtrauma. Furthermore, the disruptive influence of previous traumatic shoulder injuries may also affect subsequent tissue function and joint stability, regardless of whether surgical repair or rehabilitation was undertaken (Herrington, Horsley, & Rolf, 2010; Kawasaki et al., 2014b). Herrington et al. (2010) also showed that Rugby players with previous shoulder joint injuries had decreased joint position sense (as indicated by greater error scores) than their counterparts that had not suffered a previous shoulder injury, although it is possible that the decreased function may have also played a role in the initial injury. Kawasaki et al. (2014b) identified that players that had suffered a past traumatic shoulder dislocation were three-to-four-times more likely to sustain a subsequent traumatic dislocation to the opposite shoulder joint (odds ratio=3.56, 95% CL1.27-9.97), thereby highlighting that other factors, such as joint laxity, could confound the relationship with past injury and subsequent injury risk (Ogaki, Takemura, Iwai, & Miyakawa, 2014).

In addition to reduced shoulder joint proprioception, abnormal joint kinematics could also be symptomatic of decreased musculoskeletal function. For example, scapular dyskinesis is a kinetic abnormality of the shoulder joint that has been shown to occur

in up to one-third (32%) of shoulder joints within Rugby players (Kawasaki, Yamakawa, Kaketa, Kobayashi, & Kaneko, 2012), and may be related to a past history of sustaining a traumatic injury to the brachial plexus (often referred to as 'stinger' or 'burner' injuries) (Kawasaki et al., 2014a). A study in elite Japanese Rugby revealed that players with symptomatic and asymptomatic scapular dyskinesis were significantly more likely to report shoulder discomfort during the playing season (odds ratio=3.6 – 4.4).

The physical demands of playing Rugby have been shown to decrease aspects of neck function (e.g., range of motion, proprioception) amongst players (Lark & McCarthy, 2007). Studies comparing neck function in Rugby players against non-Rugby-playing controls have indicated that Rugby players (particularly the forward playing positions) have a much lower active cervical range of motion across extension, lateral flexion, and rotation movement planes (Lark & McCarthy, 2007), whilst cervical proprioception has been shown to be lower in Rugby players when compared with controls (Lark & McCarthy, 2007; Pinsault, Anxionnaz, & Vuillerme, 2010). Two studies by Lark and McCarthy identified that decrements in neck function could occur following a single Rugby-related exposure as well as over the course of a full playing season (2010; 2009). Linked to reduced range of motion and proprioception, neck pain may also be a common complaint in Rugby players. Watson, Hodge, and Gekis (2014) established that over half (52%) of 100 Rugby players that were questioned reported having previously suffered from neck pain, with 12% reporting neck pain at the time of questioning.

Although the implications raised by a number of studies could point towards decreased musculoskeletal function of specific body regions (e.g., shoulder, neck) from playing Rugby, there is a scarcity of studies that have assessed the role of reduced musculoskeletal function in relation to injury risk across players. Tee, Klingbiel, Collins, Lambert, and Coopoo (2016) assessed the role of movement competency (as measured by the Functional Movement Screen™) as an injury risk factor in elite adult Rugby players, demonstrating that baseline movement limitation in the lower limb was related to subsequent severe (>28 days' time-loss) contact and non-contact injury risk. The association between musculoskeletal function and injury risk in Rugby players requires further research, with a particular focus on the

association between joint range of motion, proprioception, movement competency, and pain in the upper limb and neck regions with injury risk.

2.4.5.1.7   *Technical Skill*

In addition to developing the necessary physical attributes to tolerate match-play demands, Rugby players must also execute a range of technical skills (Hendricks, Lambert, Masimla, & Durandt, 2015b). Given the relatively high risk of injury associated with contact events in Rugby, such as the tackle situation, there is a need to ensure that players are sufficiently trained to execute skills safely (Burger et al., 2014; Fuller, Brooks, Cancea, Hall, & Kemp, 2007a). Indeed, the results of several studies in Rugby indicate that good tackle and ball carrying technique may play a protective role against injury risk. A recent study in youth Rugby indicated that 'placing the head to the correct side of the ball carrier', 'using the shoulder to make contact with the ball carrier', and 'leg drive upon contact' when tackling were associated with a lower risk of concussion (Hendricks et al., 2015a). Subsequent work identified similar trends in overall tackle-related injury outcomes in youth Rugby players, with 'using the shoulder to make contact with the ball carrier' and 'using the arms to wrap the ball carrier' associated with non-injury tackle events for tacklers (Burger et al., 2016). 'Leg drive on contact with the tackler', 'performing an evasive manoeuvre', and 'fending away from contact' were associated with non-injury tackle events for ball carriers (Burger et al., 2016). Neither of the above studies accounted for the effects of limb dominance on tackle proficiency, which may also play a role in tackle technique and force transfer during tackle situations. Seminati, Cazzola, Preatoni, and Trewartha (2016) identified that tacklers adopted different biomechanical strategies when faced with tackling on their dominant and non-dominant sides, with greater neck flexion and lateral bending of the head noted in the non-dominant condition. Moreover, the authors noted that the tackle technique in the dominant condition (increased lateral bending of the trunk) was more akin to published guidelines for teaching safe and effective tackle technique (Hendricks & Lambert, 2010).

2.4.5.2 Extrinsic Risk Factors

2.4.5.2.1   Playing Position

The effect of playing position as an injury risk factor has been investigated in several studies, which have typically demonstrated trivial effects in overall injury rates between forwards and backs (Archbold et al., 2015; Bird et al., 1998; Chalmers et al., 2012; Kerr et al., 2008; Quarrie et al., 2001; Roberts et al., 2013; Roux & Goedeke, 1987). However, many of these studies focus only on comparisons of overall injury risk between forwards and backs, which ignores the susceptibility of specific playing positions to specific injury types. For instance, it has been shown that hookers may be at an increased risk of concussion compared with props, whilst scrum-halves may be at a much lower risk of concussion than forwards and other playing positions in the backs (Mc Fie et al., 2016). Moreover, back row forwards have been shown to suffer an increased rate of acute shoulder injuries compared with second row forwards (Singh, Trewartha, Roberts, England, & Stokes, 2016). In elite Rugby, Brooks and Kemp (2011) highlighted that in addition to focusing on preventive shoulder and knee injuries across all playing positions, further emphasis should be placed on reducing ankle injuries in forwards and knee injuries in backs due to the relatively high burden of these injury types in the respective playing groups.

In the case of youth Rugby players, it should be noted that individuals may sample playing across diverse playing positions in the forwards and the backs before specialising in a specific position at a later age. As such, players may not have a fixed playing position until they reach late adolescence or adulthood, making the assessment of playing position in relation to injury risk difficult in this population. This may also preclude the assessment of 'playing out of position' as a potential risk factor in youth Rugby.

2.4.5.2.2   Playing Level (Grade)

Injury risk has typically been shown to increase with increasing playing levels in Rugby (Bird et al., 1998; Quarrie et al., 2001). Palmer-Green et al. (2013) compared injury rates between schoolboy and professional academy Rugby playing populations aged 16-18 years, reporting that injury rates in the academy group were 34% higher than in the schoolboy group (47/1000 player-hours vs. 35/1000 player-hours). Compared with these incidence rates, a study conducted in international under-20 Rugby established an overall match injury incidence rate of 57/1000 match-hours (Fuller & Molloy, 2011). The reasons for the higher injury risk seen across higher playing levels of Rugby are unclear. It has been speculated that increased anthropometric and physiological fitness characteristics of players at higher playing levels may contribute to increased match-play demands and increased exposure to potentially injurious events, which also could relate to the influence of physiological fitness and anthropometric characteristics as injury risk factors (Chalmers et al., 2012; Quarrie et al., 2001).

2.4.5.2.3   Exposure Type

Injury rates in Rugby vary markedly by exposure type. Whereas match injury rates at elite level Rugby may be as high as 81/1000 player-hours, training injury rates may only be 3/1000 player-hours (Williams et al., 2013). In youth Rugby, match injury incidence rates have been shown to be 17 to 33-times higher in match-play relative to training (Palmer-Green et al., 2013, 2015). These discrepancies clearly define match-play as a higher risk activity. Reasons for the higher incidence of injury in matches may relate to the uncontrolled, open nature of contact events in matches, players engaging in risk-taking behaviour or displaying aggression to opposition players, or increased movement demands and work rates amongst players. Few studies have compared training and match-play demands in Rugby (Hartwig, Naughton, & Searl, 2011). Tee, Lambert, and Coopoo (2016) identified that professional Rugby players covered less distance overall during matches when compared with training sessions, but did cover relatively greater distances at higher speeds and engaged in more frequent episodes of sprinting during matches. Hartwig et al. (2011) also noted a similar pattern in youth Rugby match-play, with adolescent

players covering greater overall distances as well as greater time spent at higher running speeds and engaging in a greater frequency of sprint efforts during matches when compared with training. These findings suggest that the greater movement demands of match-play could contribute in part to the greater frequency of injuries, and also that existing training practices across Rugby may fail to prepare players adequately for the demands of matches, thereby predisposing players to injury.

2.4.5.2.4   Phase of Play

The majority of injuries in youth Rugby occur in the tackle situation, which accounts for approximately half of all injuries suffered (40-64%) (Freitag et al., 2015b). The tackle is considered to be an 'open' skill that can be influenced by a multitude of factors. Higher injury rates have been shown in situations where the ball carrier is tackled from behind (Garraway et al., 1999; Quarrie & Hopkins, 2008), as well as with high-speed collisions between tacklers and the ball carrier (Fuller et al., 2010a; Quarrie & Hopkins, 2008). Additionally, different running speeds between the ball carrier and tackler(s) approaching the tackle were also associated with an increased risk of injury, in 80% of cases to the player travelling at the slower speed (Garraway et al., 1999).

Many studies that identify the tackle as the most common phase of play associated with injury report injury incidence per unit of time. However, this does not account for the number of events that occur. Using propensity (injuries/1000 events) as an outcome measure, Fuller et al. (2007a) demonstrated that collision tackles (attempts to tackle without use of the arms) were the events associated with the highest frequency of injury (11 injuries/1000 events), followed by the scrum (8 injuries/1000 events), and then tackle-related injuries (6 injuries /1000 events). Similarly, a study in men's community Rugby also identified that collision tackles were associated with the highest risk of injury (15/1000 events), of which injuries to the ball carrier were particularly high when compared with the tackler (13/1000 events vs. 2/1000 events) (Roberts, Trewartha, England, & Stokes, 2015). These findings demonstrate that although the tackle is associated with the greatest frequency of injury per unit of time, it is the most common contact event across Rugby. In contrast, scrums and collision tackles carry a greater risk per event than tackles.

2.4.5.2.5   Playing Environment

The external environment in which Rugby is played may influence injury risk in players in a number of ways, with these relationships investigated in several studies. Alsop, Morrison, Williams, Chalmers, and Simpson (2005) cited pitch condition as a risk factor for injury, with firmer and harder pitches associated with a 52% greater likelihood of injury in Rugby players. Lee and Garraway (2000) also identified an association between ground condition and injury risk, with the highest injury incidence observed on hard pitches. However, this finding was confounded by early-season bias, with firmer and harder pitches observed at the start of the Rugby season when injury rates were also highest (Lee & Garraway, 2000). It is possible that factors other than pitch condition (such as readiness to play) contributed to the increased incidence of injury seen at the beginning of the playing season (Takemura, Schneiders, Bell, & Milburn, 2007). Furthermore, few studies have provided information about how pitch condition was measured, beyond subjective inferences. Takemura et al. (2007) monitored ground hardness (with a penetrometer) at systematically chosen locations across Rugby pitches, identifying that both injury rates and ground hardness decreased across the playing season, but without detecting significant associations between these variables. Other additional environmental factors that have been associated with injury risk include calm conditions and warmer temperatures (Alsop et al., 2005; Lee & Garraway, 2000). Although the underlying reasons for why these environmental factors may influence injury risk are unclear, one possibility is that the above conditions influence the styles of play and tactical approaches that teams employ (Alsop et al., 2005).

Recently, artificial playing surfaces have become an alternative playing surface to natural turf in Rugby. There are a number of benefits to using artificial surfaces, such as its ability to tolerate increased usage, low maintenance costs, and consistency across varying weather conditions. However, artificial surfaces may also influence injury risk. Two studies in Rugby demonstrated no significant differences in injury risk between artificial and natural surfaces (Fuller, Clarke, & Molloy, 2010b; Williams, Trewartha, Kemp, Michell, & Stokes, 2016). However, one study identified a non-significant trend towards an increased frequency of anterior cruciate ligament injury on artificial surfaces (Artificial surface $n = 5$ vs. Natural turf $n = 1$,

rate ratio= 3.82, 95% CL not provided) (Fuller et al., 2010b). Another study identified an almost 8-fold increase in abrasion injuries on artificial surfaces relative to natural turf (rate ratio=7.92, 90% CL 4.29-14.28), although a small minority of these abrasions resulted in any subsequent time-loss (Williams et al., 2016). It should be acknowledged that both studies were conducted in adult playing populations, with the influence of playing surface in younger Rugby players unconfirmed currently.

2.4.5.3 Inciting events

The previous two sub-sections have detailed the potential intrinsic and extrinsic risk factors that have been identified in Rugby. These characteristics may render an individual susceptible to injury, but an inciting event is required for an injury to occur (Meeuwisse, 1994). Bahr and Krosshaug (2005) proposed a need to extend the Multifactorial Model of Injury Aetiology to address other factors associated with the injury mechanism beyond describing the inciting event, such as the playing situation, player behaviour, as well as whole body and joint biomechanics at the time of injury. In providing a complete picture of events leading to the injury, this information may be of greater use in shaping prevention strategies than simply providing a biomechanical account of injury alone (Bahr & Holme, 2003).

2.4.5.4 Injury Mechanisms in Rugby Union

Studies into the mechanisms of injury in Rugby to-date have focused on severe injuries to the cervical spine arising from the scrum, and concussion and traumatic shoulder injuries arising from contact situations.

The principal mechanism of cervical spine injury in Rugby remains contentious. Early indications in the literature suggested that cervical spine injuries in Rugby were primarily brought about by a hyperflexion of the neck on the basis of player testimonies and the high proportion of cervical spine injuries being due to scrum engagement or collapse (Kuster, Gibson, Abboud, & Drew, 2012; Quarrie et al., 2002). A review of cervical spine injury mechanisms challenged this view by pointing to the relatively recent increases in cases of injuries occurring from tackle situations as opposed to scrum engagements and collapses that predominated the early literature, and also that the primary mechanism of bilateral facet joint

dislocation (usually C5-C7 vertebrae) (a specific injury type observed in rugby situations) was buckling secondary to onset of a compressive force (Kuster et al., 2012). Tackle-related spinal cord injuries are thought to be due to the transfer of a significant compressive force as opposed to hyperflexion which may precede the buckling mechanism, although these findings have been based on ex vivo cadaveric models that have yet to be translated to an in vivo model (Dennison, Macri, & Cripton, 2012).

Studies are in general agreement that acute traumatic shoulder injuries in Rugby may occur through one of three mechanisms: application of a posteriorly-directed force to a flexed arm that increases flexion (such as in the act of diving to score a try); application of a posteriorly-directed force that extends an already abducted arm (such as when making a tackle with an outstretched arm); or through a medially directed compressive force on an adducted arm (such as in contact with the ground or another player with arm by side) (Crichton, Jones, & Funk, 2012; Usman, McIntosh, Quarrie, & Targett, 2015). The outcomes of these mechanisms include leveraging forces on the shoulder joint that can produce joint dislocations, labral tears, acromioclavicular joint separations, as well as sternal and clavicular fractures (Helgeson & Stoneman, 2014).

Studies examining the mechanisms relating to concussion in elite Rugby have established that the majority of concussions and head impacts occur directly when the head of one player impacts the upper body or upper limb of a second player, as in a tackle or breakdown situation (McIntosh, McCrory, & Comerford, 2000). It has been shown that the tackler receives the head impact in most cases, in particular when the tackler places their head in front of the ball carrier instead of to the side (Tierney, Lawler, Denvir, McQuilkin, & Simms, 2016). In contrast, a study in youth Rugby indicated that concussions occurred more frequently when the anterior aspect of the head/face of one player contacted the hips or below on a second player (Hendricks et al., 2016). This discrepancy may reflect the difference in tackle techniques between youth and adult players.

Finally, a recent study in elite Rugby players identified two principal mechanisms for ACL injuries (Montgomery et al., 2016). Fifty-seven percent (57%) of ACL

injuries resulted from contact mechanisms, all of which occurred when being tackled. The remaining 43% of ACL injuries occurred through non-contact mechanisms, most of which involved a side-stepping or cutting manoeuvre. Of note, ACL injuries occurring through side-stepping were associated with initial foot contact through a heel strike, whilst knee flexion angles were lower when compared with a control group of non-injury side-steps (Montgomery et al., 2016).

2.4.6 Summary

This section has highlighted that there are numerous intrinsic and extrinsic risk factors that can influence injury risk in individual Rugby players. Many of the studies to have identified risk factors in Rugby-playing cohorts have been conducted in adult playing levels or pooled youth and adult populations to date, which invites the question of how some of the risk factors mentioned above could relate to injury risk in youth Rugby players specifically.

2.5 Introducing a Preventive Measure

Once the extent of the injury problem has been established and potential causative factors and mechanisms associated with injury have been identified, it is possible to then begin to formulate preventive strategies to reduce injury risk. This section first considers the steps that are necessary for developing a preventive strategy for sports injury prevention, followed by an outline of the existing preventive measures that have been implemented within Rugby.

2.5.1 Frameworks for formulating Preventive Interventions

Both the Sequence of Injury Prevention and TRIPP frameworks identify that preventive strategies need to be developed on the basis of existing knowledge of the injury patterns and aetiological factors within specific settings (Finch, 2006; Van Mechelen et al., 1992). However, guidance on which steps to follow in developing a preventive strategy has been lacking in the literature. Recently, Donaldson et al. (2016b) proposed a staged framework that could be applied to developing any preventive strategy (Figure 2.6). To begin with, knowledge of the injury patterns and risk factors for injury should be gathered to ensure that the preventive strategy is based on sound scientific theory and evidence. In addition, the clinical expertise of

relevant practitioners may also be sought to complement scientific evidence. Subsequent steps include seeking the views of experts and end users in ensuring that the preventive strategy is specific to the sport and injury mechanisms of interest, whilst also considering the acceptability of the preventive strategy to prospective users. The preventive strategy should then be tested for feasibility and acceptability amongst end users who may provide feedback on any proposed changes. The next stage involves evaluating the preventive strategy against a relevant theory, such as the diffusion of innovations theory (Oldenburg & Glanz, 2008), to enhance the possibility that the programme will be adopted and maintained by end users. Finally, feedback on the preventive strategy (content and presentation) should be sought from end users and delivery agents to ensure any final changes can be made before evaluating the preventive strategy.
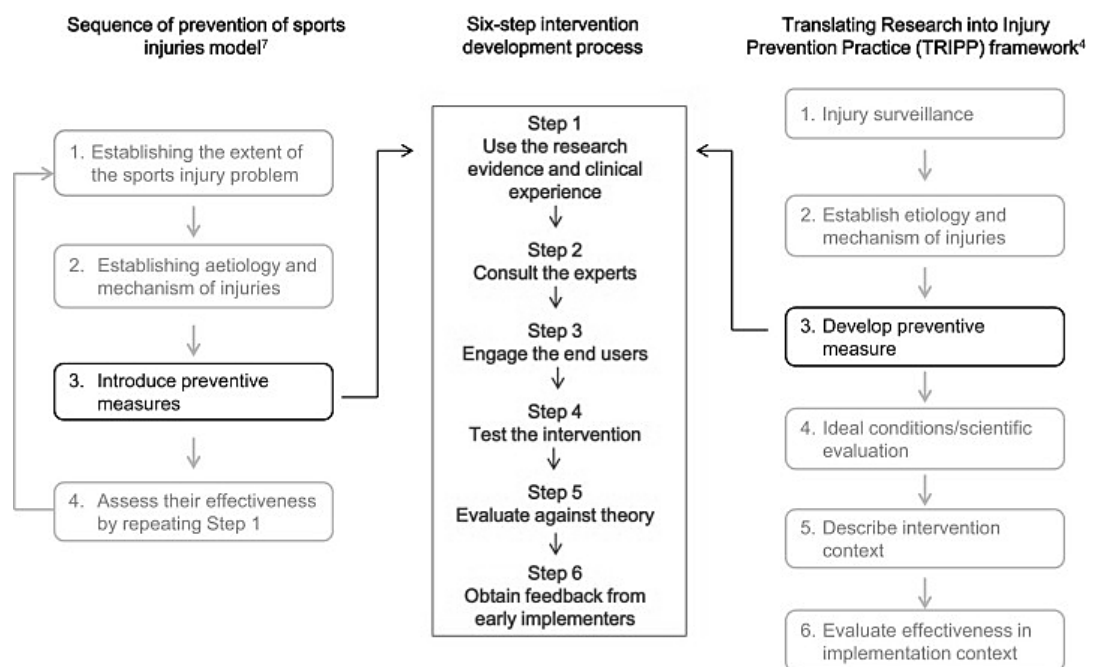
Figure 2.6   A Generalisable Process for developing Sports Injury Prevention Interventions (Donaldson et al., 2016b), and how this framework relates to the Sequence of Prevention and TRIPP models.

A similar approach to preventive strategy development was proposed by Padua et al. (2014). Many similarities exist between the two models, although Padua et al. also stressed the need to establish administrative support from sporting organisations before proceeding with programme development.

2.5.2 Existing Preventive Measures in Rugby Union

2.5.2.1 Playing Law / Regulation Amendments

Law changes represent one of the most effective means of reducing injury, given that compliance with their use is mandatory and can reach all potential end beneficiaries. The relatively high propensity for injury during the Rugby scrum (Fuller et al., 2007a; Roberts et al., 2015) has understandably lead to several attempts to reduce the risk of potentially catastrophic injuries arising from the engagement of rival packs and the scrum collapsing to the floor. A series of recent studies demonstrated that amending the scrum engagement process to incorporate a "pre-bind" requirement on opposing props prior to engagement was associated with reductions in the set-up distance between opposing packs by 27% and engagement speed by more than 20% (Preatoni, Cazzola, Stokes, England, & Trewartha, 2015). These changes to the engagement process consequently lead to reduced biomechanical loads acting on front row players of between 14-25% at engagement (Cazzola, Preatoni, Stokes, England, & Trewartha, 2015; Preatoni et al., 2015). The demonstrated reductions in biomechanical load may have implications for reducing acute cervical spine injuries, as well as preserving long-term neck health amongst players. Whether the scrum engagement law change is associated with reduced catastrophic injury risk remains to be evaluated, although a recent study in French Rugby indicated that altering the scrum engagement process by withdrawing the 'hit' led to a reduction in catastrophic injury risk post-implementation of 44% (absolute difference=0.8 injuries/100,000 players) (Reboursiere et al., 2016).

Other law amendments to prevent injury have targeted instances of illegal tackles, such as tip/spear tackles (a tackler lifting the ball carrier from the ground before dropping them such that they land on their back, neck, or head) or collision tackles (a

tackler making no attempt to wrap arms around the ball carrier) through seeking to increase sanctions applied to players (Murray, Murray, & Robson, 2014). Most recently, a global directive has sought to lower the height of the tackle by redefining high tackle categories and increasing sanctions applied to high tackles (World Rugby, 2016). At present, it is not clear whether this approach has led to changes in tackle-related injury risk.

2.5.2.2 Coach / Official Education

Coaches and match officials are well-placed to shape the behaviours of players, particularly at youth age groups. Therefore, educating these stakeholder groups may offer a means of reducing injury risk in Rugby. In New Zealand and South Africa, education programmes have been shown to influence injury outcomes amongst Rugby playing populations. New Zealand's "Rugby Smart" programme was designed to provide coaches and officials with evidence-based information about injury risk and prevention strategies (Gianotti, Quarrie, & Hume, 2009). Quarrie, Gianotti, Hopkins, and Hume (2007) demonstrated that spinal injury risk was reduced by 54% and scrum-related spinal injury risk by 89% following the introduction of the 'Rugby Smart' programme. Additionally, Gianotti et al. (2009) reported that targeted injury types were reduced following implementation of 'Rugby Smart', with knee injuries reduced by 21%, neck/spine injuries reduced by 23%, and leg injuries (excluding knee and ankle injuries) reduced by 19%. The same study also identified improvements in player behaviours relating to safe techniques for the tackle, scrum, and the ruck (Gianotti et al., 2009).

Following the principles of 'Rugby Smart', 'BokSmart' was adapted and implemented across South African Rugby and similarly targeted the education of coaches and officials. Recent evidence has suggested that the introduction of the 'BokSmart' programme coincided with a 40% reduction in catastrophic injury risk in youth Rugby with an absolute difference of 2.5 fewer catastrophic injuries per year (Brown, Verhagen, Knol, Van Mechelen, & Lambert, 2016b). The underlying reasons for this reduction may relate to the effects of the 'BokSmart' programme on safety behaviours amongst players, with the results of two studies revealing positive changes on player behaviours, specifically relating to practising safe tackle and

scrum techniques (Brown, Gardner-Lubbe, Lambert, Van Mechelen, & Verhagen, 2014; Brown, Gardner-Lubbe, Lambert, van Mechelen, & Verhagen, 2016a). These results highlight that targeting the education of coaches and officials can lead to improvements in player safety behaviours and potentially reduced injury risks, although no studies have associated changes of player behaviours with concomitant changes in injury risk at present.

2.5.2.3 Protective Equipment

Considering the contact-orientated nature of Rugby, the use of protective wear is permitted amongst players. Research into the efficacy of protective wear in Rugby has been directed at head guards, gum shields, and shoulder pads. Gum shields have been shown to be the most commonly used piece of protective wear amongst Rugby players, with Marshall et al. (2001) documenting that players wore gum shields for almost 70% of exposures. By contrast, players only wore head guards at 14% of exposures. The high proportion of players that used gum shields may reflect the perception amongst players that gum shields can reduce injury risk. Studies have shown that gum shield use for Rugby can reduce dental injury risk by 43%, and orofacial injury risk by 44% (Marshall et al., 2005; Quarrie, Gianotti, Chalmers, & Hopkins, 2005). On the other hand, the low rate of head guard use may be related to player views that they can be uncomfortable to wear (Finch, McIntosh, & McCrory, 2001), and may not necessarily reduce the risk of severe injury types (Marshall et al., 2005; McIntosh et al., 2009).

Shoulder pads (compressible foam material) may be used in Rugby, and are typically worn to attenuate impact forces during contact situations (Gerrard, 1998). Shoulder padding has been shown to reduce peak force during tackle situations by 40% in a lab-based setting, although this reduction was localised over the acromioclavicular joint (Pain, Tsui, & Cove, 2008). Moreover, commercially available shoulder pads may not sufficiently attenuate significant impact forces, and as such may not afford much protection from serious shoulder injuries (Harris & Spears, 2010).

2.5.3   Summary

Until recently, there has been little guidance on the steps required to develop a prevention strategy in the sports injury literature. Despite this, a number of preventive measures have been evaluated in Rugby, with varying success. The amendment of the scrum engagement process offers promise in reducing both acute catastrophic injury risk and also the likelihood of long-term neck dysfunction, whilst the introduction of coach and official education programmes have coincided with substantial reductions in severe injury risk and improvements in the safety behaviours of players. Finally, gum shields have been shown to reduce dental and orofacial injury risk in Rugby, but head guards and shoulder pads have had a limited effect on reducing injuries in Rugby.

2.6   The influence of Behavioural Factors in Sports Injury Prevention Research

As stated in the TRIPP Model (Finch, 2006), there is a need to advance beyond determining efficacy of preventive measures in controlled settings and begin to understand how preventive strategies will be received in the real world. In particular, attention should be paid to understanding the contexts into which strategies will be implemented and how behavioural factors may influence implementation (Verhagen, Van Stralen, & Van Mechelen, 2010). It is possible that future sports injury prevention measures may only be successfully taken up and maintained if the underlying behavioural determinants of safety behaviours are sufficiently well-understood (McGlashan & Finch, 2010).

2.6.1   Behaviour Modification Models

When seeking to understand safety behaviours and their underlying determinants, it is helpful to do so using established behavioural change frameworks, as these can provide a way to conceptualise how established behavioural constructs may act together to produce a desired safety behaviour (McGlashan & Finch, 2010). However, a review of 100 articles revealed that only eleven of the included studies had applied an established behavioural change model in the context of sports injury

prevention (McGlashan & Finch, 2010), thereby illustrating that relative scarcity of studies of this nature.

Amongst the studies included in the review that had adopted established behavioural change models, the theory of planned behaviour (or theory of reasoned action) was the most common, whilst the health belief model, and social cognitive theory were also noted. These models may be collectively referred to as 'motivational models'. Motivational models focus on the underlying motivational factors behind an intention to perform a health behaviour or avoid a risk behaviour (Armitage & Conner, 2000). According to motivational models, intention to act is often the variable of interest and is explained by a combination of underlying factors such as perceived behavioural control, social norms, self-efficacy, perceived susceptibility and severity, perceived barriers, health motivation, and outcome expectancies as established behavioural constructs. A few studies in sports injury prevention have measured theory constructs but did not attempt to address their association with intention or subsequent behaviours (Finch et al., 2014b; White et al., 2014). In contrast, one study that assessed intention to wear protective equipment amongst in-line skaters (using theory of planned behaviour constructs) indicated that instrumental attitudes (i.e. usefulness of protective equipment), and subjective norms made significant contributions to the prediction of intention to use protective equipment (Deroche, Stephan, Castanier, Brewer, & Le Scanff, 2009). Additionally, an earlier study that also assessed the influence of behavioural determinants on protective equipment use amongst in-line skaters (using health belief model constructs) revealed that perceived barriers to wearing protective equipment, perceived susceptibility to injury, and perceived benefits of wearing protective gear were significant predictors of protective gear use (Williams-Avery & Mackinnon, 1996). Soligard et al. (2010) identified that perceived barriers to using a preventive exercise programme amongst youth soccer coaches were associated with programme compliance (using health belief model constructs). Specifically, youth soccer coaches that believed a preventive exercise programme was too time consuming were 87% more likely to have poor compliance with use, whilst coaches that believed that the programme did not contain enough sport-specific content were 81% more likely to have poor compliance with use.

A principal limitation of motivational models such as the health belief model and theory of reasoned action is that they imply that developing an intention to act is a sufficient precursor to adopting and maintaining a new behaviour (Armitage & Conner, 2000). Motivational factors can correspond poorly with subsequent behaviours, as demonstrated by the "intention-behaviour gap" that can exist in certain settings (Sniehotta, Scholz, & Schwarzer, 2005a), and so forming an intention to act will not necessarily guarantee the adoption of a new behaviour.

2.6.2   *The Health Action Process Approach (HAPA) Model*

The Health Action Process Approach (HAPA) Model is a theory of health behaviour change that suggests the adoption, implementation, and maintenance of a new health behaviour is a process containing two distinct phases: a *motivational phase*, and a *volitional phase* (Figure 2.7) (Armitage & Conner, 2000). The *motivational phase* is characterised by *pre-intenders* forming an intention to adopt a new behaviour. Underpinning this intention to act in the motivational phase are task self-efficacy and outcome expectancies, with risk perception being viewed as a more distal factor (Schwarzer et al., 2003). Once an intention has been formed, *intenders* then move to the *volitional phase* where the intention must be translated into behaviour through developing action and coping plans, which are aided by task- and maintenance self-efficacy. Once the behaviour has been enacted, perceived maintenance and recovery self-efficacy govern influence action control to maintain the behaviour, which can be influenced by external barriers and resources that facilitate or inhibit maintenance of the behaviour (Schwarzer et al., 2003). The HAPA Model has been applied across various health domains, such as engaging in physical activity (Lippke, Ziegelmann, & Schwarzer, 2004b, 2005; Sniehotta et al., 2005a), breast screening (Luszczynska & Schwarzer, 2003), dietary behaviour (Schwarzer et al., 2007), and outpatient rehabilitation adherence (Clark & Bassett, 2014).
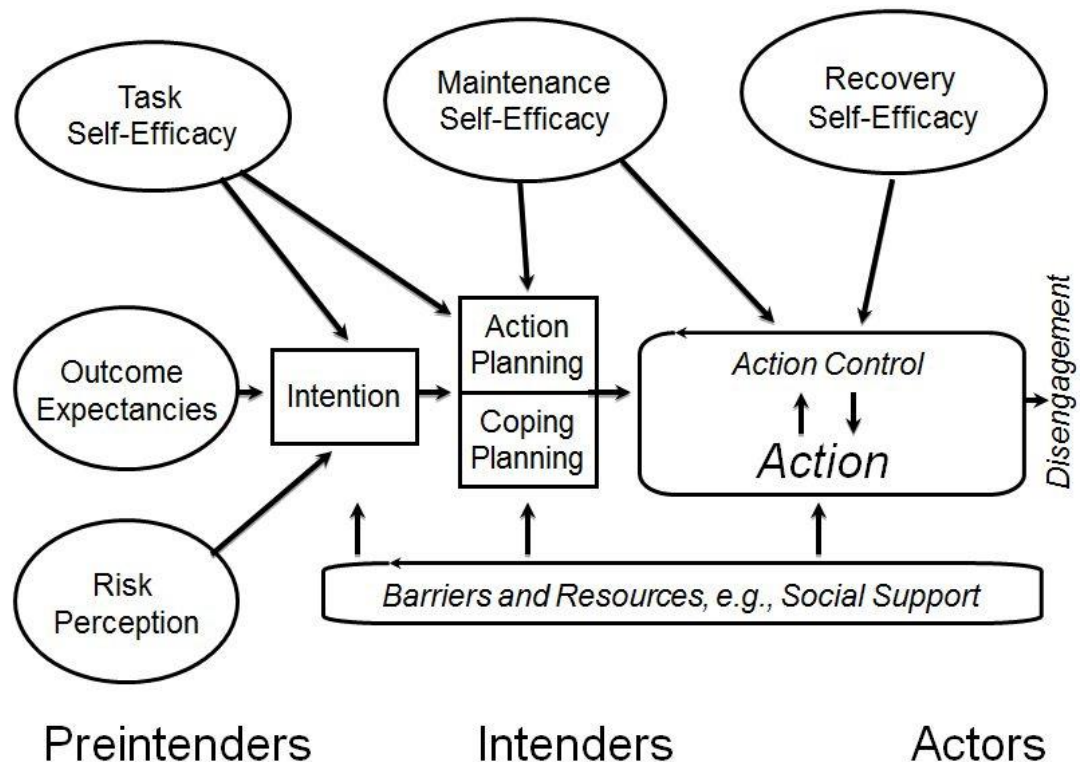
Figure 2.7   The Health Action Process Approach (HAPA) Model (Schwarzer, 2014)

There are several reasons why the HAPA Model may be appropriate for use in an injury prevention context. Firstly, the model accounts for more proximal factors to behaviour (e.g. action / coping planning, maintenance self-efficacy) than motivational models (i.e. health belief model), which may only focus at the motivational stage. Secondly, whereas other behaviour change models may be targeted towards positively-framed behaviours, such as engaging in physical activity for enjoyment, the inclusion of risk perceptions and outcome expectancies in the HAPA model may suit this model for injury prevention, which would be classed as an avoidance-based behaviour (McKay, Merrett, & Emery, 2016). Finally, the inclusion of factors that relate to maintenance of health behaviours (i.e. action control, recovery self-efficacy) following adoption represents a further step beyond many other models, and in the case of preventive strategies that require ongoing use to reduce injury risk (such as preventive exercise programmes), the HAPA Model may be well-suited to identifying the challenges of implementation in a sports injury prevention context. That said, only a few studies in sports injury prevention have

assessed the role of behavioural determinants using the HAPA Model, all of which have been conducted in female youth soccer. McKay, Meeuwisse, and Emery (2014a) identified that the HAPA model provided a good model fit for coach questionnaire responses. Moreover, the study results established that risk perception, outcome expectancies, and task self-efficacy accounting for almost 93% of the variance in intention to use the FIFA 11+ exercise programme (McKay et al., 2014a). McKay et al. (2016) also highlighted that task self-efficacy (i.e., perceived capability to understand and use the FIFA 11+ exercise programme) was the only motivational factor to be associated with intention to implement the FIFA 11+ exercise programme amongst coaches, which was supported by the findings of subsequent work by Owoeye et al. (2017a) in a similar demographic of coaches. So far, no studies have moved beyond the motivational phase of the HAPA model to assess the influence of other proximal factors to behaviour in relation to sports injury prevention.

2.6.3   Summary

This section outlines that there is a need to understand the underlying determinants for safety behaviours in sports injury prevention research. Through this approach, it may be possible to identify the role of these factors in predicting intention and adoption of new behaviours. However, the scarcity of research in this domain signals that this approach remains in its infancy in the sports injury literature. Several models have been investigated, but their appropriateness for investigating the role of behavioural determinants of adopting injury prevention is questionable. The HAPA model is one model that may be well-suited to researching the determinants of sports injury prevention, with early evidence suggesting that the model can provide a good fit for coach-related behavioural factors. Moreover, early evidence supports task self-efficacy as an important factor for intention forming in relation to adopting a preventive exercise programme. Further research is needed to move beyond the motivational phase of the HAPA model and identify the role of proximal factors to adopting and maintaining use of preventive exercise programmes.

2.7   Rationale for the current programme of work

This literature review has identified that injuries can pose several health-related, financial, and social threats to stakeholders in full-contact sports. Current evidence supports that whilst injury incidence rates in youth Rugby are lower than adult professional and sub-elite Rugby, they may be considered higher than, or at least comparable with, other youth team contact sports and therefore merit investigation to reduce injury risk. This review also demonstrates that youth Rugby players may be exposed to a multitude of intrinsic and extrinsic risk factors, yet there have been few studies to investigate modifiable risk factors for injury specifically within youth Rugby players. Furthermore, many of the identified risk factors, such as age and exposure type, are non-modifiable and there is a need to identify modifiable risk factors to inform the development of appropriate preventive strategies. A number of preventive measures exist within Rugby, but modifying training practices or physical conditioning strategies have been an under-investigated feature of these injury prevention measures at present. Additionally, there is a need to understand the behavioural determinants for safety behaviours across sports to inform the implementation attempts of preventive measures. Research efforts appear to be in their infancy owing to only a few attempts to apply established behavioural modification frameworks at present.

CHAPTER THREE

The influence of selected Anthropometric and Physical Fitness Characteristics on Injury Risk in Schoolboy Rugby Players

3.1   Introduction

Injuries are a potential consequence of an individual being exposed to interactions between dynamic risk factors and inciting events (Meeuwisse et al., 2007). Identifying the underlying risk factors for injury is regarded as a basis from which to inform preventive strategy formulation and classify at-risk populations (Van Mechelen et al., 1992).

Studies concerned with risk factor identification in Rugby have sampled predominantly senior playing levels. From these studies, player workloads (Brooks, Fuller, Kemp, & Reddin, 2008; Cross, Williams, Trewartha, Kemp, & Stokes, 2016; Williams et al., 2017), playing position (Brooks & Kemp, 2011), and a history of injury (Cross et al., 2015a; Hollis et al., 2009) have been identified as prospective risk factors for injury in adult Rugby players. However, many of these findings were the result of univariate analysis between prospective risk factors and injury, thereby not accounting for the multifactorial nature of injuries (Meeuwisse, 1994).

By and large, few studies have documented the independent effects of injury risk factors within Rugby players when controlling for other possible factors (Chalmers et al., 2012; Quarrie et al., 2001). Furthermore, the comparability and consistency of effects across these studies have been impaired by several methodological limitations, such as disparities in the measures adopted for risk factors and injury definitions. In some cases, study samples have also comprised pooled samples of youth and adult Rugby players, and so age-related associations between risk factors and injury may be masked or not be specific to younger players. Overall, the contribution of specific risk factors to injury in young Rugby players remains largely unknown.

Based on the limited evidence available for youth Rugby players specifically, increasing age and playing level are risk factors which have been supported by

empirical evidence (Archbold et al., 2015; Haseler et al., 2010; McIntosh et al., 2010). Injury incidence has also been shown to be higher in youth Rugby match-play than training, highlighting exposure type as an additional risk factor (Palmer-Green et al., 2013, 2015). However, these risk factors are non-modifiable and consequently challenging to target with interventions. Identifying potentially modifiable risk factors in youth Rugby players is therefore warranted.

Features of anthropometric and athletic profile advance progressively in adolescent Rugby players with puberty and exposure to training methods to enhance performance (Durandt et al., 2009; Till, Cobley, O'Hara, Chapman, & Cooke, 2013). Adaptations in player physique and physical capabilities may contribute to increasingly physical match play demands in youth Rugby (Archbold et al., 2015; Haseler et al., 2010; Palmer-Green et al., 2013). Higher playing levels across adult Rugby-playing populations has been associated with an increased frequency of contact situations (Roberts et al., 2015), and increased force magnitudes expressed during contact situations (Hendricks et al., 2014; Quarrie & Hopkins, 2008). The physical demands of youth Rugby Union and how these relate to adult playing levels remain poorly understood, but a similar pattern of increase could be present with advancing youth Rugby age groups. Size mismatches between players of similar chronological ages have also been raised as a concern in relation to injury risk in youth collision sports (Malina & Beunen, 1996; Nutton et al., 2012; Tucker et al., 2016). The anthropometric and athletic profiles of youth Rugby players are relatively well-described (Darrall-Jones et al., 2015, 2016; Delahunt et al., 2013; Durandt et al., 2009), but few studies have attempted to establish how these characteristics could influence injury risk.

The identification of injury risk factors that can be modified is central to developing appropriate and effective preventive strategies. Despite this, the existing evidence base points to a lack of understanding of which potentially modifiable risk factors influence injury risk in youth Rugby players.

3.1.1   Aims of Chapter

This chapter aims to investigate the association between several player-related anthropometric and physical performance characteristics with injury incidence in a population of schoolboy Rugby players.

3.2   Methods

3.2.1   Study Design and Setting

This was a two-season prospective cohort study that was conducted during the 2013 and 2015 school winter terms (late August to early December of both years) across several independent schools within England.

3.2.2   Participants

This study's inclusion criteria stipulated that schools provided rugby across the U15-U18 age groups, had on-site medical provision (for instance, on-site provision of a school medical centre or physiotherapist), and were not employing any specific movement correction practices as part of the players' existing training programme. Fourteen schools were initially approached to participate in this study, from which twelve eligible schools participated at the start of the 2013/14 playing season. Five schools dropped out of the study during season one, and three schools provided no in-season exposure or injury data but were retained for season two. Nine schools were approached for season two (seven schools retained from season one and two new schools), of which four declined to participate. Five schools subsequently commenced season two, none of which dropped out of the study. Following the conclusion of the 2015/16 playing season, injury and exposure data were retrieved from eight separate schools, with one school providing exposure and injury data from both the 2013/14 and 2015/16 playing seasons (nine school-seasons overall).

As part of the recruitment procedure, all coaches provided informed consent (in loco parentis) for their respective teams to participate in this study. All U15, U16, and U18 players who were present on the arranged date of pre-season testing for each school provided informed assent to participate in this study. The study procedures were approved by the Research Ethics Approval Committee for Health (REACH) at the University of Bath.

3.2.3   Data Collection

Individual risk factor variables in this study were included based on evidenced associations with injury outcomes in youth and adult contact sport populations, with

additional consideration for the time constraints of testing teams during the pre-season. A test battery comprising nine measures was selected (4 anthropometric, 5 athletic performance), from which thirteen variables were extracted (5 anthropometric, 8 athletic performance).

Pre-season testing sessions were conducted locally at each of the schools' premises and all players were briefed on the test order and procedures at the commencement of each session. The order of the test battery was standardised for all testing sessions. The testing session began in an indoor space with the Functional Movement Screen™ (FMS), followed by isometric mid-thigh deadlift pull, and anthropometric measurements (Standing height, body mass, and body composition). Sprint tests over 10 and 40m and the Yo-Yo Intermittent Recovery Test (Level 1) were all conducted on a natural turf surface. All players followed separate standardised warm-up protocols before completing the isometric mid-thigh pull and the sprints. Warm-up protocols prior to the isometric mid-thigh pull consisted of mobilisation and activation exercises, and prior to the sprint tests also included a series of mobilisation exercises with some rehearsal of sprint mechanics.

3.2.3.1 Functional Movement Screen

Movement competency was assessed using the Functional Movement Screen™ (Functional Movement Systems, VA, USA). The FMS™ is comprised of 7 discrete movements that are subjectively assessed for movement quality, per established criteria (Cook, Burton, & Hoogenboom, 2006a, 2006b). FMS™ testing across both seasons was conducted by a small team of pre-trained assessors from the wider research team. Testing was conducted on a flat indoor space and followed a standardised sequence. Players were shown a central demonstration with standardised verbal coaching points and cues for each of the 7 movement patterns by the research team before being assessed individually in smaller groups. The movement patterns incorporated in the FMS™ included: Hurdle Step, Deep Squat, In-line Lunge, Active Straight Leg Raise, Rotary Stability, Shoulder Mobility, and Trunk Stability Press-up. Each player was allowed three attempts to perform each movement pattern (or three for each lower / upper limb in the case of unilateral movements). Upon completion of the central demonstration and initial relay of

coaching points for each exercise, no further verbal instructions were relayed to players by the research team.

Scoring followed the standard FMS™ procedure, where each movement pattern was subjectively scored on a scale of 0-3. A score of *3* indicated performance of the movement pattern without any movement dysfunction; *2* indicated performance of the movement pattern with some movement dysfunction; *1* indicated a failure to complete the movement pattern; and *0* indicated the presence of pain whilst the player attempted the test. Three of the seven movement patterns also had attached "clearing" tests (rotary stability, shoulder mobility, and trunk stability press up). Clearing tests were assessed on whether pain was experienced during the movement pattern. If in the instance that a player reported experiencing pain during a clearing test, that individual's performance on the associated movement pattern would also score a *0*. The composite score for each individual was the sum of scores of each of the seven movement patterns, with the total possible score being *21* (Cook et al., 2006a, 2006b). For five of the movement patterns that assessed the left and right sides separately, a difference in scores between the left and right sides indicated a movement asymmetry. In cases where an asymmetry was detected, the lower of the two scores was added to the composite score. Assessing the test-retest reliability of the FMS was not possible in this study due to time constraints, however reports from the literature indicate that the intra-rater test-retest reliability of the FMS is "good" (ICC=0.60 to 0.74) (Shultz, Anderson, Matheson, Marcello, & Besier, 2013; Teyhen et al., 2012).

3.2.3.2 Anthropometric Testing

Anthropometric and body composition measures were collected in accordance with the procedures specified by Eston and Reilly (2009), and Utter et al. (1999), respectively. All anthropometric measures were conducted with the players bare-footed and wearing t-shirts and shorts. Standing height and seated height were both recorded to the nearest 0.1 cm using a free-standing stadiometer (Leicester Height Measure, SECA, UK). Body mass and composition (via Leg-to-Leg Bioelectrical Impedance) were assessed to the nearest 0.1 kg and 0.1%, respectively (SC-240 body composition monitor, Tanita, USA).

Estimated maturity offset for each individual was calculated from the height measures and chronological age, according to the gender-specific regression equations developed by Mirwald et al. (2002). The outcome of the equation represented years to (negative years) or from (positive years) peak height velocity.

3.2.3.3 Isometric Mid-thigh Pull

An isometric mid-thigh deadlift pull was selected to measure the maximum strength of players, using a bar attached by a chain to a fixed dynamometer and platform. Test instructions were provided by the research team, along with a practical demonstration. Players were instructed to stand with their feet at a comfortable width apart on the platform with the dynamometer between their legs. Taking an overhand shoulder-width grip of the bar, players assumed a half-squat position. Specific coaching points about maintaining a rigid and neutral spine, driving through the heels, and pinching the medial edges of the shoulder blades together were given throughout the test. Each participant was provided with two prior attempts for familiarisation and for the researchers to assess technical proficiency: the first at 50% of their perceived maximum force capacity, and then 75% of their perceived maximum force capacity. Providing that they had demonstrated safe form during the familiarisation attempts, players performed a final repetition at their maximum force capacity, which was recorded. Test-retest reliability was assessed in a subset of 114 players, the typical error and coefficient of variation for within-player change scores were 11.2 kg and 7.6%, respectively.

3.2.3.4 10 and 40 m linear sprint

The sprint speed of players was evaluated through completion of a 10 and 40 m linear sprint attempt. The test was conducted using dual beam electronic timing gates (Brower timing systems, UT, USA) positioned at 0 m, 10 m, and 40 m marks. Each player began their attempt by adopting a standing two-point stance 0.5 m behind the first pair of gates. The 0-10 m split and total time to sprint 40 m were recorded to the nearest 0.1 s. Average running speed was calculated by dividing the distance covered (10 and 40 m, respectively) by the time elapsed (s). Initial sprint momentum (kg.m.s^{-1}) was calculated as the product of the average sprint speed (m.s^{-1}) attained over 10 m and the individuals' body mass (kg). The typical error and coefficient of

variation for within-player change scores in sprint speed were 0.2 m.s^{-1} and 3.6% for 0-10 m, and 0.1 m.s^{-1} and 1.7% for 0-40 m, respectively.

3.2.3.5 Yo-Yo Intermittent Recovery Test

Players concluded the test battery by completing the Yo-Yo IRT-1 to provide an estimate of aerobic capacity. The test involved players running repeated 2 x 20 m shuttles. Each 2 x 20 m shuttle was followed by a 10 s period of active recovery, whereby participants were required to walk back and forth to a line of cones which were 5 m beyond the finish line (Bangsbo, Iaia, & Krustrup, 2008). Shuttles needed to be maintained in time with a series of audible cues played from a sound system. The running speed to complete each shuttle (defined by the time elapsed between audible cues) gradually increased as the test levels advanced. Players were permitted one warning if they failed to complete a shuttle in the allotted time. A second warning for a player signalled the end of their test. The final figure recorded for each player was the last full shuttle that they completed in the allotted time, expressed in multiples of 40 m. Due to time constraints, test-retest reliability of the Yo-Yo IRT-1 was not conducted in this study, but reproducibility of the test has been demonstrated reported elsewhere (Typical error= 17 m; Coefficient of variation= 4.9%) (Krustrup et al., 2003).

3.2.3.6 Match exposure reporting

The definition of a reportable match exposure was tailored from the consensus statement for injury definitions and data collection procedures in rugby (Fuller et al., 2007b):

"Play between teams from different schools, where the specified match play duration or maximum number of players on the field at any one time were not shortened"

Festival or tournament fixtures (typically lower match durations), and abbreviated versions of the game such as rugby 7s and 10s (fewer than 15 players per team allowed on the field during match play), were not deemed reportable match exposures for this study. Team coaches prospectively completed an exposure report form for reportable match exposures on a weekly basis. The exposure report form

captured information regarding each fixture (opponent, date, result) and a list of players who were involved in the fixture (starting players and replacements). For weeks where two fixtures were played, coaches completed an additional exposure report form.

3.2.3.7 Injury reporting

The school medical centre or physiotherapist, in liaison with team coaches and players, tracked and recorded relevant injury data from the players. The definition of a reportable injury was also adapted from the recommended consensus statement (Fuller et al., 2007b):

"Any physical complaint sustained during a reportable school rugby match that leads to a player being unable to take a full part in any planned physical activity for greater than 24 hours after infliction of the index injury."

Coaches began the injury reporting process by logging the date of injury, injured player's ID number and playing position at the time of the injury, and event causing the injury. Injured players then visited the school medical centre or other on-site medical professional for the injury to be logged and treated. The medical professional supplied an injury diagnosis and injured body location on a paper-based or electronic injury report form. When an injured player was ready to make a full return to play, their coach made a note on the injury report form of the date that the individual participated fully in training and was considered ready for match selection.

3.2.4   Statistical Analyses

Statistical Analyses were undertaken with IBM SPSS Statistics for Windows, Version 22.0 (IBM Corporation, Armonk, NY, USA). Continuous predictor variables were analysed with a squared term to identify any non-linear associations with injury incidence. Any continuous predictor variables displaying a statistically significant non-linear relationship with injury incidence ($P<0.05$) were converted into tertiles and subsequently treated as categorical variables (Cortina, 1993). The injury incidence rate was calculated as the number of injuries per 1000 player match-exposures. Incidence rate ratios (Incidence RR) and 90% confidence limits (90%

CL) were analysed using generalised linear modelling with a Poisson distribution, a log-linear link function, and offset for exposure in both univariate and multivariate analyses. Univariate analyses between each continuous predictor variable and injury incidence were assessed by comparing the Incidence Rate Ratio (RR) of a two between-player standard deviation (SD) increase in the predictor variable. This difference can best be regarded as the increase from a typically low value of a predictor variable (Mean-1SD) to a typically high value ((Mean+1SD) (Hopkins, 2010)). Univariate analyses between each categorical predictor variable and injury incidence were assessed by comparing the incidence rate ratio of all other categories with a reference category within each predictor variable.

Effect sizes for associations between each predictor variable and injury risk were assessed against a pre-set smallest worthwhile effect on incidence RR, using a spreadsheet for deriving confidence limits and a mechanistic inference from a p-value (Hopkins, 2007). The smallest worthwhile reduction was given by an incidence RR of 0.90 (i.e.: a 10% reduction in incidence rate). Conversely, the smallest worthwhile increase was given as an incidence RR of 1.11 (i.e.: an 11% increase in incidence rate) (Hopkins, 2010). Effects were treated as *unclear* if the 90% CL for the incidence RR crossed both thresholds for smallest worthwhile effects by >5% (i.e.: effect could be both substantially lower and higher than smallest worthwhile effects). Effects were qualified against pre-defined probabilistic terms from the following scale: <0.5%, most unlikely; 0.5-5%, very unlikely; 5-25%, unlikely; 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; >99.5%, most likely (Batterham & Hopkins, 2006).

For the multivariate model selection, age group was included regardless of the outcome of the univariate analysis. Other predictor variables were included if univariate associations between predictor variables and injury incidence were deemed to be clear (i.e. percentage likelihoods that effect was lower and higher than smallest worthwhile effects were not both greater than 5%).

3.3   Results

3.3.1   Player and Injury Characteristics

Pre-season testing was conducted with 1,010 players across fourteen schools over the course of the study (U15: 316; U16: 245; U18: 449). Data collected from six schools and 611 players (U15: 178; U16: 153; U18: 280) were excluded from analysis due to dropout following pre-season testing, or failure to return complete match exposure or injury data for the duration of the playing season. A sample of 399 players across eight schools were retained for analysis (13/14: 150; 15/16: 249). Characteristics of the final sample of players are outlined by age grouping in Table 3.1.

Injury characteristics categorised by age group are outlined in Table 3.2. Overall, 3,829 player-match-exposures were reported. A total of 101 (>24 hours) time-loss match injuries were reported from 88 players, translating to an injury incidence rate of 26 injuries/1000 player-match-exposures (90% CL: 22 to 31). Thirty-four injuries were sustained by U15 players, 19 injuries by U16 players, and 48 injuries by U18 players. The lower limb was the most commonly injured location (11/1000 match-exposures), followed by the head/neck (7/1000 match-exposures), and upper limb (7/1000 match-exposures). Most injuries resulted from contact events (22/1000 player-match-exposures), with fewer occurring through non-contact mechanisms (2/1000 player-match-exposures).

Table 3.1   Player Characteristics by age group

Age group		U15	U16	U18	Overall
Players (*n*)		138	92	169	399
Standing height (cm)		173.4 ± 7.2	177.1 ± 7.4	178.7 ± 6.1	176.5 ± 7.2
Body mass (kg)		67.1 ± 11.8	73.6 ± 14.4	78.6 ± 10.3	73.5 ± 12.9
BMI (kg.m^{-2})		22.3 ± 3.3	23.3 ± 3.6	24.6 ± 3.3	23.5 ± 3.5
Body composition (%)		15.4 ± 5.9	15.9 ± 5.8	15.0 ± 5.4	15.3 ± 5.7
Maturity Offset *n* (%)	>1 year post-PHV	43 (31%)	67 (73%)	164 (97%)	124 (31%)
	≤1 year post-PHV	95 (69%)	25 (27%)	5 (3%)	275 (69%)
FMS composite Score (/21)		14 ± 2	14 ± 3	15 ± 2	15 ± 2
FMS ≥ 1 movement asymmetry (%)		55%	61%	66%	61%
FMS ≥1 instance of pain (%)		16%	12%	18%	16%
IMTP (kg)		118.5 ± 27.9	138.7 ± 26.8	156.4 ± 27.4	140.4 ± 31.8
40 m sprint speed (m.s^{-1})		6.6 ± 0.4	6.8 ± 0.5	7.0 ± 0.4	6.8 ± 0.5
10 m sprint speed (m.s^{-1})		5.1 ± 0.3	5.2 ± 0.4	5.3 ± 0.4	5.2 ± 0.4
Sprint momentum (kg.m.s^{-1})		340.5 ± 62.3	383.1 ± 76.9	412.4 ± 58.5	381.3 ± 71.5
Yo-Yo IRT-1 (m)		923 ± 399	1134 ± 533	1102 ± 452	1045 ± 462

Data presented as mean ± SD. BMI – Body Mass Index. FMS – Functional Movement Screen. IMTP – Isometric mid-thigh deadlift pull. IRT – Intermittent Recovery Test.

Table 3.2   Match injury characteristics by age group

Age group	U15	U16	U18	Overall
Player Match Exposures (*n*)	1,479	794	1,556	3,829
Match Injuries (*n*)	34	19	48	101
Match Injury Incidence	23 (17-29)	24 (15-33)	31 (24-38)	26 (22-31)
Injury Incidence by Location				
Lower Limb	11 (6-15)	9 (3-14)	12 (7-16)	11 (8-13)
Head / Neck	5 (2-8)	8 (2-13)	9 (5-13)	7 (5-9)
Upper Limb	5 (2-8)	5 (1-9)	10 (6-14)	7 (5-9)
Trunk	3 (0-5)	3 (0-5)	1 (0-2)	2 (1-3)
Injury Incidence by Event				
Contact	20 (14-26)	21 (13-30)	24 (17-30)	22 (18-26)
Non-contact	1 (0-3)	3 (0-5)	2 (0-4)	2 (1-3)
Other	2 (0-4)	0	5 (2-8)	3 (1-4)

Data presented as frequencies (*n*), or as injury incidence (per 1000 player-match-exposures) with 90% CL, where specified.

3.3.2   *Univariate Analysis of Risk Factors*

Results of the univariate risk factor analyses are illustrated in Figures 3.1 to 3.3. No statistically significant non-linear effects were identified for any continuous predictor variables. Univariate analyses revealed clear associations between several anthropometric characteristics with injury incidence. A two standard deviation (2SD) increase in standing height was associated with a 56% increase in injury risk (Incidence RR= 1.56, 90% CL 1.17 to 2.07, *very likely higher*), whilst a 2SD increase in body mass was similarly associated with a 57% increase in injury risk (Incidence RR= 1.57, 90% CL 1.18 to 2.08, *very likely higher*). A 2SD increase in Body Mass Index corresponded with a 40% higher injury incidence (Incidence RR= 1.40, 90% CL 1.03 to 1.88, *likely higher*). By contrast, *unclear* associations were noted for a 2SD increase in body composition with injury incidence (Incidence RR=

1.18, 90% CL 0.85 to 1.63, *unclear*), as well as for maturity offset with injury incidence (Incidence RR= 0.85, 90% CL 0.58 to 1.24, *unclear*).
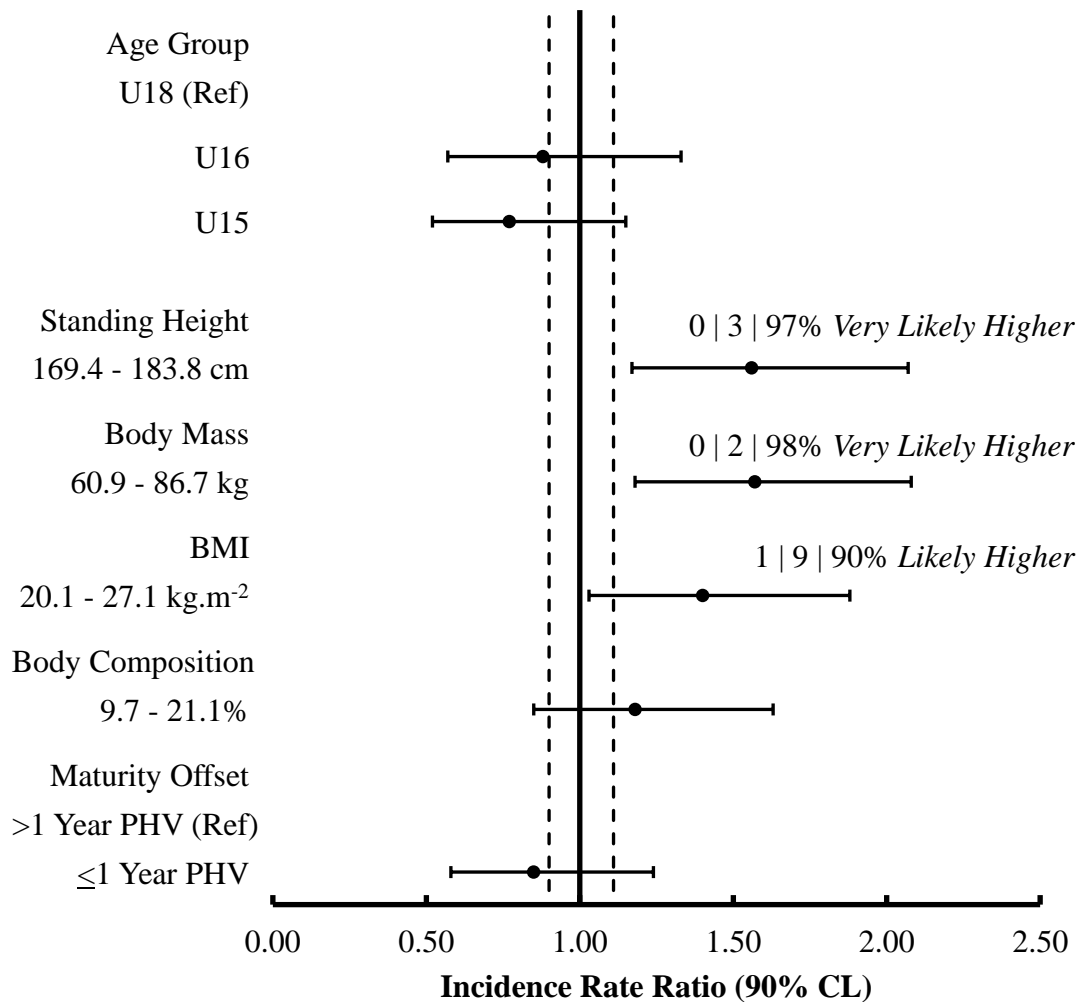
Figure 3.1   Forest Plot illustrating the associations between age group and anthropometric measures with injury incidence. Values below titles to the left of the y-axis represent mean-1SD to mean+1SD across continuous predictor variables. Dotted vertical lines represent thresholds for smallest worthwhile effects (Incidence RR= 0.90 and 1.11). Data labels represent % likelihood that each effect is lower | trivial | higher than smallest worthwhile effects for variables that demonstrate a clear association with injury incidence. BMI – Body Mass Index. PHV= Peak Height Velocity.

Several physical performance characteristics were also clearly associated with injury incidence (Figure 3.2). A 2SD increase in mean composite FMS score was associated with a 27% reduction in injury incidence (Incidence RR= 0.73, 90% CL 0.50 to 1.05, *likely lower*). Moreover, players with no left-right asymmetries across any of the five FMS unilateral movement patterns were at a lower injury risk when compared with players who had one or more asymmetries (Incidence RR= 0.73, 90% CL 0.49 to 1.08, *likely lower*). A 2SD increase in isometric mid-thigh pull force was associated with a 69% increase in injury risk (Incidence RR= 1.69, 90% CL 1.14 to 2.53, *very likely higher*), whilst a 2SD increase in sprint momentum was associated with a 53% increase in injury risk (Incidence RR= 1.53, 90% CL 1.10 to 2.12, *likely higher*). In addition, a 2SD increase in sprint speed over 10 m (Incidence RR= 0.94, 90% CL 0.66 to 1.33, *unclear*) and 40 m (Incidence RR= 0.96, 90% CL 0.67 to 1.38, *unclear*) demonstrated trivial associations with injury incidence, as did a 2SD increase in distance covered in the Yo-Yo Level 1 Intermittent Recovery Test (Incidence RR= 0.91, 90% CL 0.61 to 1.34, *unclear*).

Associations between FMS sub-test scores and injury incidence are illustrated in Figure 3.3. Players with identified movement limitations on the Hurdle Step were associated with a 65% increase in injury incidence when compared with players who had no evident movement limitations (Incidence RR= 1.65, 90% CL 0.91 to 3.02, *likely higher*). Reported pain on the Active Straight Leg Raise (Incidence RR= 6.30, 90% CL 1.92 to 20.60, *very likely higher*), Shoulder Mobility (Incidence RR= 1.85, 90% CL 1.02 to 3.35, *likely higher*), and Trunk Stability Press Up movement patterns (Incidence RR= 2.27, 90% CL 1.20 to 4.29, *very likely higher*) were also associated with increased injury incidence. The associations between injury incidence with movement limitation or pain on the deep squat, in-line lunge, rotary stability were all *unclear*.
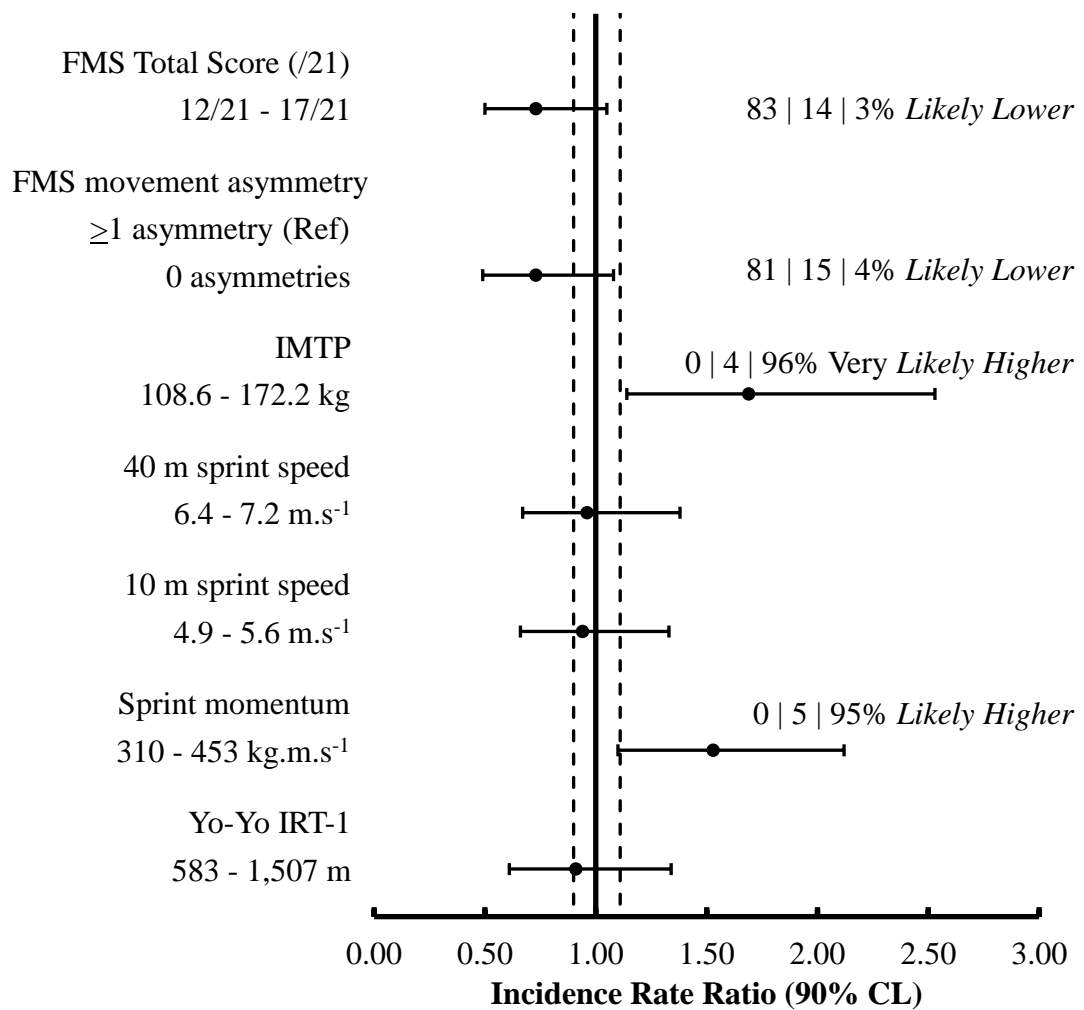
Figure 3.2   Forest Plot illustrating the associations between physiological fitness measures with injury incidence. Values below titles to the left of the y-axis represent mean-1SD to mean+1SD across continuous predictor variables. Dotted vertical lines represent thresholds for smallest worthwhile effects (Incidence RR=0.90 and 1.11). Data labels represent % likelihood that each effect is lower | trivial | higher than smallest worthwhile effects for variables that demonstrate a clear association with injury incidence. IMTP – Isometric Mid-thigh Deadlift Pull, Yo-Yo IRT-1 – Yo-Yo Intermittent Recovery Test Level 1.
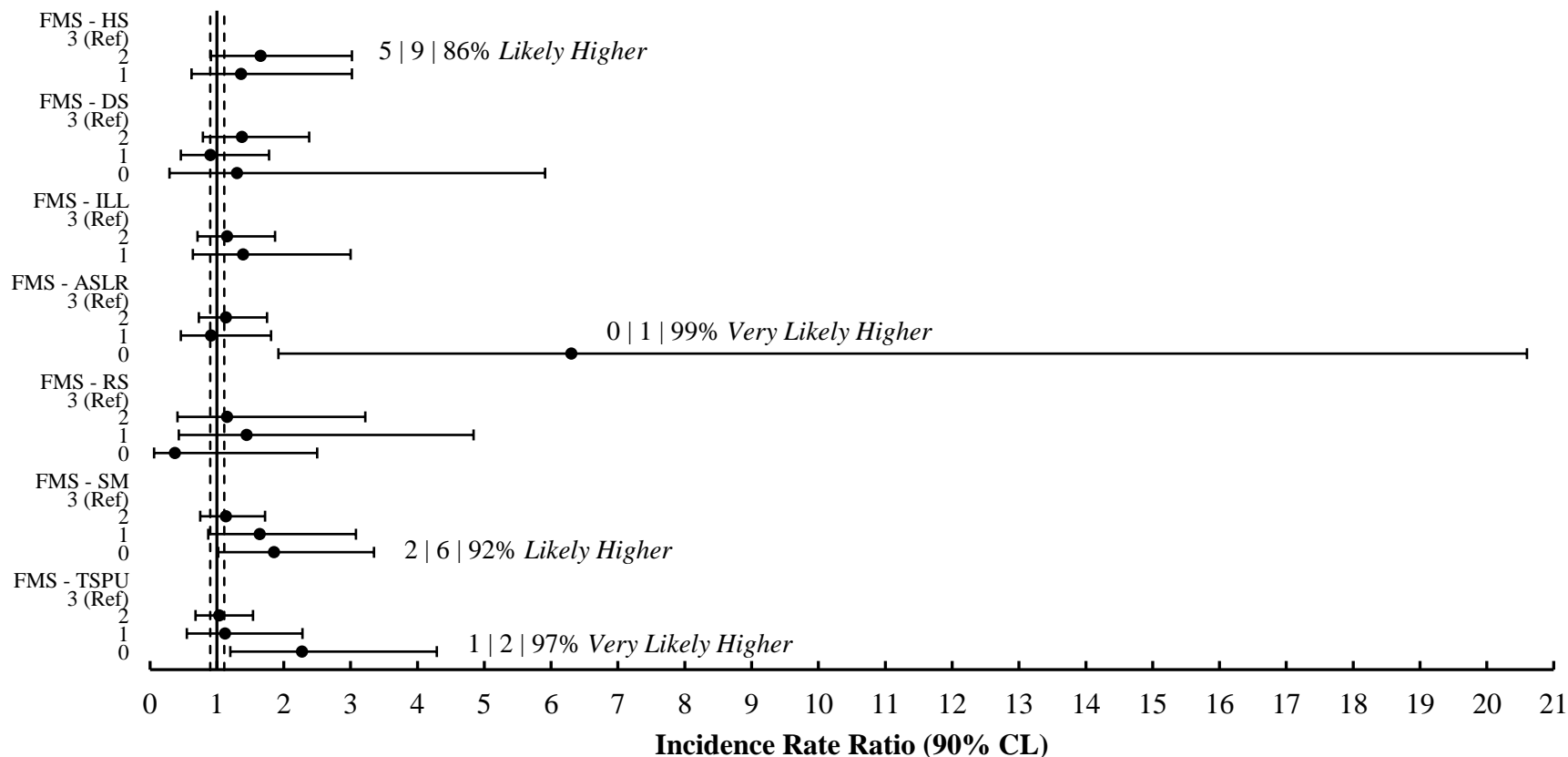
Figure 3.3   Forest plot illustrating the associations between FMS sub-tests and injury incidence. Dotted vertical lines represent thresholds for smallest worthwhile effect (Incidence RR= 0.90 and 1.11). Data labels represent % likelihood that each effect is lower | trivial | higher than the smallest worthwhile effects for variables demonstrating a clear association with injury incidence. HS – Hurdle Step. DS – Deep Squat. ILL – In-line Lunge. ASLR – Active Straight Leg Raise. RS – Rotary Stability. SM – Shoulder Mobility. TSPU – Trunk Stability Press Up.

3.3.3   Multivariate Analysis of Risk Factors

A combination of age group, standing height, body mass, total FMS score, Hurdle Step, Active Straight Leg Raise, Shoulder Mobility, and Trunk Stability Press Up, detection of FMS asymmetry, IMTP force, and sprint momentum were included in the multivariate model. Data for the active straight leg raise, shoulder mobility, and trunk stability press up movement patterns were pooled into binary variables comprised of players who reported experiencing pain during the movement patterns (i.e. scored a *0/3*) and players who did not (i.e. scored a *1, 2,* or *3/3*). Data from 125 players were withdrawn from the multivariate model due to incomplete data for the selected variables. The remaining sample of 274 players, 2,772 match exposure, and 66 injuries was taken for multivariate analysis.

Results of the multivariate analysis are illustrated in Figure 3.4. Clear associations were noted between injury risk and increasing standing height (Incidence RR= 1.50, 90% CL 0.93 to 2.42, *likely higher*), reporting pain during the ASLR (Incidence RR= 5.13, 90% CL 1.75 to 14.99, *very likely higher*), and reporting pain during the TSPU or its attached clearing test (Incidence RR= 2.87, 90% CL 1.32 to 6.27, *very likely higher*). Demonstrating no asymmetries on the FMS was associated with a protective effect on injury incidence when compared with demonstrating one or more asymmetries (Incidence RR= 0.66, 90% CL 0.41 to 1.07, *likely lower*). No other clear associations were noted for the remaining variables.
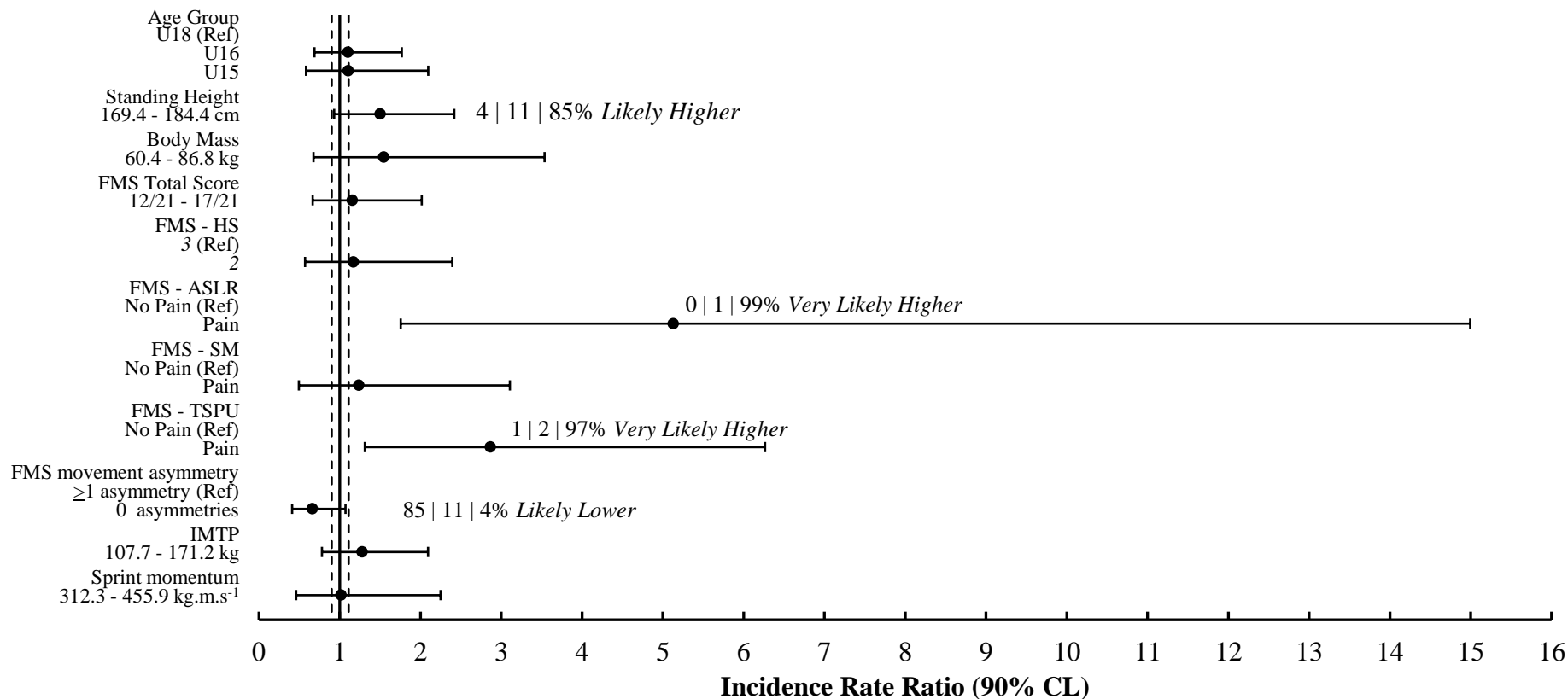
Figure 3.4   Forest plot illustrating the multivariate-adjusted associations between anthropometric and physical performance measures with injury incidence. Dotted vertical lines represent thresholds for smallest worthwhile effect (Incidence RR= 0.90 and 1.11). Data labels represent % likelihood that each effect is beneficial | trivial | harmful for variables demonstrating a clear association with injury incidence. HS – Hurdle Step. ASLR – Active Straight Leg Raise. SM – Shoulder Mobility. TSPU – Trunk Stability Press Up. IMTP – Isometric mid-thigh Deadlift Pull

3.4 Discussion

This study aimed to investigate the associations between several player-related anthropometric and physical performance characteristics with injury incidence in schoolboy Rugby players. Clear univariate associations were established between injury incidence and standing height, body mass, overall movement competency, detected regional pain, detected bi-lateral movement asymmetry, isometric mid-thigh pull force, and sprint momentum. Multivariate analysis of the above variables and age group revealed that increased standing height and detected pain during the active straight leg raise and trunk stability push up movement patterns were clearly associated with an increased match injury incidence. Having no bi-lateral movement asymmetries was associated with lower injury incidence when compared with having one or more asymmetries.

In this study, taller and heavier players were associated with 50-60% increases in time-loss injury incidence. A clear association was noted between increasing standing height with increasing injury incidence following multivariate analysis, which accounted for age group amongst other factors. The nature of how anthropometric characteristics influence injury risk has proved inconclusive in pooled analyses of youth and adult Rugby players (Chalmers et al., 2012; Quarrie et al., 2001), although clearer conclusions have been drawn in schoolboy Rugby players. A recent study in 16-18-year-old Irish schoolboy Rugby players identified a statistically significant association between increased body mass with increased injury incidence (Archbold et al., 2015). A univariate association was documented between increasing body mass with increasing injury incidence in this study, but this association was rendered *unclear* following multivariate analyses. The lack of a clear association following multivariate analysis may point to the confounding influence of age group, whereby the older cohorts were both heavier and suffered an increased incidence of injuries compared with younger age groups.

Increasing standing height remained clearly associated with increasing injury incidence following multivariate analysis that controlled for factors such as age group. The underlying reasons for the increased injury incidence with increasing standing height are not clear. Physical maturity has been postulated as an injury risk

factor that may mediate the relationship between anthropometric development and injury incidence in youth sports (Johnson, Doherty, & Freemont, 2009; Le Gall, Carling, & Reilly, 2007). However, physical maturity (defined as years to or from age at peak height velocity) was not clearly associated with injury in this study, possibly due to most players being estimated to be more than 1-year post-peak height velocity (69% of the overall sample).

Maturity-induced variation in growth can lead to substantial morphological differences between players within the same age banding (Malina & Beunen, 1996; Nutton et al., 2012). Size mismatches have been thought to place smaller players at an increased injury risk in sports which feature frequent player-to-player contact situations. (Brust, Leonard, Pheley, & Roberts, 1992; Caine, Maffulli, & Caine, 2008). However, studies which implicate physical mismatches as an injury risk factor in contact sports are scarce (Krause et al., 2015). The independent association between increasing standing height with increasing injury incidence in this study indicates a contrasting association, whereby taller players were at an increased risk of injury. This finding could relate to the point that changes in anthropometry and physical performance do not occur simultaneously in young athletes. Krause et al. (2015) documented that only 6% of 485 early to mid-adolescent Rugby players (aged 11-15 years) shared the highest age-specific tertiles for body mass, relative peak power, and sprint speed. In light of that finding, anthropometrically advanced youth Rugby players that lack the physical capacity to tolerate match-play demands may have been predisposed to injury (Backous, Friedl, Smith, Parr, & Carpine, 1988).

The playing styles and technical competencies developed by taller youth Rugby players may also have contributed to their increased risk of injury. Anthropometrically advanced youth Rugby players may be more likely to regard their physical size as an advantage than their less physically developed counterparts (Krause et al., 2015). From a tactical perspective, physically advanced youth players may be more inclined to rely on their physique than technical abilities during match-play events where being physically advanced carries benefit (Hendricks et al., 2014). Allied to this, physically advanced youth players may not develop sufficient technical competence during the formative years of training and match-play (Gabbett, 2009; Gabbett, Jenkins, & Abernethy, 2010). The competitive advantages

conferred by being physically advanced during early to mid-adolescence may dissipate during late adolescence when most players have completed puberty. At this point, players who are reliant on their body size may be predisposed to injury because of poor technique during high risk playing events, such as the tackle situation (Burger et al., 2016; Hendricks et al., 2015a).

Recent thoughts about reducing injury risk in youth Rugby have proposed for players to be grouped by maturational status or physical size (i.e.: bio-banding) instead of chronological age (Batten, White, Anderson, & Bullingham, 2016; Carter, 2015; Tucker et al., 2016). This study's findings urge caution in grouping youth players predominantly by anthropometric profile without considering additional factors, such as physical or technical capabilities, as this may limit the intended prophylactic effect. Meanwhile, further research is warranted in identifying the underlying mechanisms by which anthropometric profile influences injury risk in youth Rugby players. Particular consideration should be paid towards the development of physical and technical competencies in players of varying anthropometric profile.

Asymmetries in bi-lateral musculoskeletal function have been shown to predispose to injury and impair sporting performance (Chapman, Laymon, & Arnold, 2014; Croisier, Ganteaume, Binet, Genty, & Ferret, 2008; Kiesel, Butler, & Plisky, 2014). Results of the multivariate analysis in this study noted an independent protective effect of having no evident bi-lateral movement asymmetries from the FMS. Players with no bilateral asymmetries suffered 34% fewer time-loss injuries than players with at least one detected movement asymmetry. Bilateral asymmetries appear common in field sport athletes, such as soccer (Lehance, Binet, Bury, & Croisier, 2009) and Australian Rules football (Fuller et al., 2016). Moreover, a trigger point has been proposed whereby asymmetries become more pronounced in young athletes who are post-peak height velocity (Atkins, Bentley, Hurst, Sinclair, & Hesketh, 2016). The prevalence of having at least 1 asymmetrical movement pattern amongst players in this study was 61%. This proportion was similar to studies which documented that 61% of youth elite soccer players (Lehance et al., 2009), and 65% of youth elite Australian Rules football players demonstrated at least 1 asymmetry in limb function (Fuller et al., 2016). Previous injury (Brughelli, Cronin, Mendiguchia,

Kinsella, & Nosaka, 2010), limb preference (Fousekis, Tsepis, & Vagenas, 2010), and inter-limb discrepancies in specific characteristics, such as strength and flexibility, may be associated with developing asymmetries (Croisier et al., 2008; Daneshjoo, Rahnama, Mokhtar, & Yusof, 2013a). Taken together, the findings of a high prevalence of asymmetry and the link between having no asymmetries with reduced injury incidence in this study suggest that strategies to correct asymmetries may be a warranted addition to existing training practices in youth Rugby players. Targeted unilateral training interventions may be best-placed to improve the technical and physical aspects of asymmetry and reduce injury risk (Bodden, Needham, & Chockalingam, 2015; Kiesel, Plisky, & Butler, 2011)

Experiencing pain on the Active Straight Leg Raise and Trunk Stability Press Up movement patterns were both independently associated with increased injury incidence following multivariate analysis, highlighting a novel finding of this study. Sixteen percent (16%) of players in this study reported pain on one or more of the seven FMS sub-tests. This proportion contrasts with 38% of junior elite Australian Rules footballers who reported pain on at least 1 FMS sub-test during late pre-season testing in a recent study (Fuller et al., 2016). The discrepancy could reflect the importance of performing baseline movement screening early in the pre-season phase, so as to minimise the influence of high workloads and muscle soreness on pain reporting. Few studies have presented the associations between pain detected on the FMS and injury risk, although Bushman et al. (2015) concluded that pain detected during the deep squat, hurdle step, in-line lunge, trunk-stability press up, and rotary stability movement patterns was associated with an increased likelihood of subsequent injury in military soldiers.

The detection of pain in players within this study could be ascribed to several underlying causes. Having suffered a previous injury can influence subsequent reporting of pain on the FMS (Fuller et al., 2016). Schoolboy Rugby players in this study were 34% more likely to report at least one instance of pain on the FMS if they had reported an injury incurring more than 21 days' absence from physical activity in the 12 months preceding testing (OR= 1.34). Suffering a previous injury is a prominent risk factor for many soft-tissue injury types, partly because of disruption caused to the structure and function of soft tissues which may predispose to re-injury

if not adequately rehabilitated (Emery, 2003; Fulton et al., 2014). Pain may also be considered part of a pathologic continuum that precedes injury (Crow et al., 2010), and may be symptomatic of a decrement in tissue structure or function prior to the occurrence of injury (Bahr, 2009). Finally, pain may be an overt result of underlying musculoskeletal abnormalities in players that could lead to subsequent time-loss (Iwamoto et al., 2005). Given the potential implications raised by detecting pain during the FMS in this study, identifying and treating the sources of pain arising from movement screening may be of substantial clinical importance for preventing injury and re-injury in adolescent Rugby players.

The finding that only two of the seven FMS sub-tests were independently associated with injury of this study highlights the potential to tailor movement screening in targeting susceptible injury locations as they relate to players' sporting backgrounds. The robust association between pain on the Active Straight Leg Raise and Trunk Stability Press Up with injury incidence in this study may reflect the distribution of injury locations sustained by youth Rugby players. The shoulder (16%) was the most commonly injured upper body location, whilst the ankle (20%), thigh (8%), and knee (8%) were the most commonly injured lower limb locations. Injuries to the shoulder (Hodhody, Mackenzie, & Funk, 2016), and posterior thigh (Brooks, Fuller, Kemp, & Reddin, 2006; Devlin, 2000) also have a high recurrence rate in Rugby players. Therefore, screening with these two individual movement patterns for the purpose of identifying pain in susceptible body locations could optimise primary and tertiary injury prevention strategies in youth Rugby players (Hewett, Ford, Hoogenboom, & Myer, 2010).

The main limitation of this study arose from focusing on overall injury incidence in analyses, as opposed to specific injury types. It would be unlikely that risk factors would contribute equally to all injury types. Combining disparate injury types could have masked or diluted the associations between specific risk factors and separate injury types. For instance, the association between the rotary stability movement pattern and injury incidence may have been masked by pooling relevant injury types with other injuries that shared no association with this movement pattern. This may be remedied in future studies by identifying and targeting certain injury types to assess against specifically selected risk factors, although this approach should be

considered against the likely resulting loss of statistical power or a requirement for greater study sample size.

3.5   Conclusion

In this study, anthropometric and physical performance characteristics were associated with injury incidence in youth Rugby players. Standing height remained associated with injury risk following multivariate adjustment, highlighting taller players as an at-risk group in this population. Detecting pain during the Active Straight Leg Raise and Trunk Stability Press Up movement patterns on the FMS was also associated with increased injury incidence following multivariate adjustment, whilst demonstrating no movement asymmetries was protective against injury. Priorities for movement screening in young Rugby players may be the identification and correction of pain and asymmetry, rather than movement limitation. In addition, it may be preferable for certain isolated movement patterns to be incorporated into truncated or modified pre-participation or return-to-play protocols for youth Rugby players.

CHAPTER FOUR

Exploring the process of developing a Preventive Exercise Programme for use in Schoolboy Rugby Union

4.1   Introduction

The Sequence of Prevention model (Van Mechelen et al., 1992) and the Translating Research into Injury Prevention Practice model (Finch, 2006) are two of the most widely adopted frameworks in the sports injury prevention literature (Klügl et al., 2010). Both frameworks specify that preventive measures should be developed following detailed investigations into the magnitude of the injury problem within a population, identification of priority injury types to be prevented, and analysis of potentially modifiable risk factors that influence injury risk. Depending upon the population of interest, this approach may be limited at present in being able to inform the development of preventive measures as research largely remains at the early levels of these frameworks (Chalmers, 2002; Klügl et al., 2010; McBain et al., 2012b). That is, the scale of the injury problem may have been established but the risk factors and mechanisms of injury are not typically well characterised.

Overreliance on scant scientific evidence at the expense of knowledge of the environment into which a preventive strategy will be implemented may hinder the potential benefits of a preventive strategy because of limited uptake (Donaldson et al., 2016b; Hanson et al., 2014). Conversely, overemphasising current practice or anecdotal evidence in developing a preventive strategy is also unlikely to prove effective on the basis that the underlying mechanisms by which a preventive strategy reduces injury risk are not sufficiently understood (Finch, 2006). These two considerations highlight that developing a preventive intervention should rely on research-based evidence where it is considered sound, but should seek to integrate evidence with expert views and the perceptions of end users (Ageberg, 2016; Donaldson et al., 2016b). Until recently, there have been few attempts to encapsulate evidence-based practice, expert opinion, and end users' views into a cohesive process specifically for developing a sports injury prevention strategy, consequently leading to little available guidance on the steps required to generate an evidence-

based, context-appropriate preventive strategy (Donaldson et al., 2016b; Padua et al., 2014).

Preventive exercise programmes have become an established tool in reducing musculoskeletal injury risk across a number of sporting settings (McBain et al., 2012a, 2012b). Several evidence-supported protocols now exist, including the Fédération Internationale de Football Association (FIFA) "11+" and "Prevent Injury and Enhance Performance" (PEP) programmes (Emery, Roy, Whittaker, Nettel-Aguirre, & Van Mechelen, 2015; Herman, Barton, Malliaras, & Morrissey, 2012; Thorborg et al., 2017), but the underlying processes for their development and implementation are often unreported or described in insufficient detail. For example, information on the development of the most widely researched preventive exercise programme, the FIFA "11+", is limited to a brief outline of the broad steps taken within the article that reports the results of the efficacy trial (Soligard et al., 2008). By contrast, the "Footy First" preventive exercise programme developed for use in community-level male Australian football is supported by a series of studies that detail the steps taken in developing and implementing the programme (Andrew et al., 2013; Donaldson et al., 2015; Donaldson, Lloyd, Gabbe, Cook, & Finch, 2016a; Donaldson et al., 2016b; Finch et al., 2014a; Finch et al., 2014b; Finch et al., 2013; Finch et al., 2015)

It is clear that a "one size fits all" approach to developing and implementing a preventive strategy does not exist. Publicising the steps taken to develop preventive measures may help with promoting acceptability to end users. Highlighting the underlying rationale for the steps taken in generating a preventive strategy may also contribute towards generating a consensus process for developing evidence-based, context-appropriate preventive measures across the wider sports injury prevention literature.

4.1.1   Aims of Chapter

The aim of this chapter is to outline, in detail, the processes followed in developing and implementing a preventive movement control exercise programme for use by coaches in schoolboy Rugby. In doing so, this chapter presents a systematic, context-

appropriate process to developing a preventive exercise programme, which is both evidence- and theory-informed.

The primary steps taken in developing the preventive exercise programme are illustrated below in figure 4.1, and will be described more fully in turn:
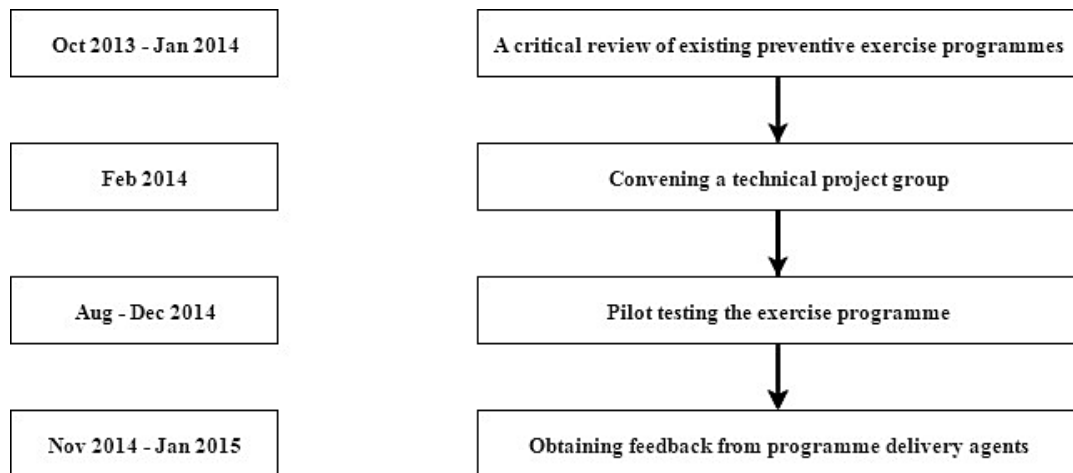
Figure 4.1   Flow diagram detailing the steps taken in developing a preventive exercise programme to be used in youth Rugby.

4.2   A review of the literature regarding the efficacy of preventive exercise programmes

The first step in developing the preventive exercise programme involved sourcing and synthesising the findings from the literature concerning previously-devised preventive exercise training protocols, as well as injury patterns in youth Rugby (October 2013 to January 2014). This step was necessary for judging the strength of evidence regarding preventive training programmes that have been used in other sports, and for identifying the features of existing programmes' structure and content that may contribute to enhancing or hindering efficacy in the context of youth Rugby. The inclusion of Rugby-related injury information helped to place the features and content of previous programmes in the context of available

epidemiological and aetiological evidence of injury patterns in youth Rugby, by identifying features and content of programmes that may be effective if applied to preventing injury in a population of Rugby players or, conversely, where certain priority injury types for prevention in Rugby may not be sufficiently targeted by existing programmes.

When considering the literature, it was clear that a number of preventive exercise programmes existed (Herman et al., 2012; Hübscher, Zech, & Pfeifer, 2010a). However, several protocols required the use of specialist equipment, such as balance boards, that could limit applicability because of increased financial costs and the possibility of limited availability of such equipment in team-based contexts (Emery, Cassidy, Klassen, Rosychuk, & Rowe, 2005; Emery & Meeuwisse, 2010; Emery, Rose, McAllister, & Meeuwisse, 2007; Hupperets, Verhagen, & Van Mechelen, 2009; Olsen, Mykelbust, Engebretsen, Holme, & Bahr, 2005; Pasanen et al., 2008; Verhagen et al., 2004). Nonetheless, eight articles were identified that had successfully demonstrated the efficacy of five separate preventive exercise programmes in reducing injury risk amongst predominantly female soccer-playing populations (Table 4.1).

Table 4.1   Summary of the structure and content of existing evidence-based preventive exercise programmes

Authors	Participants	Preventive Exercise Programme
Mandelbaum et al. (2005)	Female soccer players, aged 14-18 years	**Prevent Injury and Enhance Performance Programme (PEP)**
Gilchrist et al. (2008)	Female soccer players, mean age 20 years	Running-based warm-up Stretching – Trunk and Lower Limbs Resistance Exercises Plyometric exercises Soccer-specific agility exercises 20 minutes

Table 4.1 cont.

Soligard et al. (2008)	Female soccer players, aged 13-17 years	**F-MARC "11+"** Running-based warm-up Active stretching Lower limb resistance exercises Lower limb balance exercises Plyometric exercises Soccer-specific agility exercises
Longo et al. (2012)	Male basketball players, aged 11-24 years	
Grooms, Palmer, Onate, Myer, and Grindstaff (2013)	Male soccer players, aged 18-25 years	20 minutes
Kiani, Hellquist, Ahlqvist, Gedeborg, and Byberg (2010)	Female soccer players, aged 13-19 years	**"HarmoKnee"** Running-based warm-up Muscle activation exercises Lower limb balance exercises Lower limb resistance exercises Trunk/hip stability exercises 20-25 minutes
LaBella et al. (2011)	Female soccer/basketball players, mean age 16 years	**Knee Injury Prevention Programme (KIPP)** Resistance exercises Plyometric exercises Balance exercises Agility exercises 20 minutes
Coppack, Etherington, and Wills (2011)	Female and male military recruits, aged 17-25 years	**Anterior Knee Pain Preventive Training Programme (AKP PTP)** Lower limb closed-chain resistance exercises Lower limb balance exercises Lower limb stretching exercises 15 minutes

F-MARC – FIFA Medical Assessment and Research Centre

The earliest developed programme, named "Prevent Injury and Enhance Performance" (PEP) (Pollard, Sigward, Ota, Langford, & Powers, 2006), combined 5 components: running-based warm-up; stretching, strengthening, plyometrics, and agility exercises that took 20 minutes to complete once delivery was familiarised. The primary aim of the PEP programme was to reduce Anterior Cruciate Ligament (ACL) injuries resulting from non-contact mechanisms. Mandelbaum et al. (2005) first investigated the use of the PEP programme in a cohort of adolescent female community soccer players across two playing seasons. Results indicated 74-89% reductions in ACL injury rates during both seasons in teams that used the PEP programme, compared with a cohort of teams that continued with their usual warm-up practices (Season 1 Relative Risk (RR)=0.11, 95% Confidence Limit (CL) 0.03-0.48; Season 2 RR=0.26, 95% CL 0.09-0.73). A subsequent randomised controlled trial evaluated the efficacy of the same protocol in female collegiate soccer players over a shorter 12 week period (Gilchrist et al., 2008). Although results did not reveal significant differences in overall ACL injury rate, there were strong trends towards reductions in the risk of sustaining training-related noncontact ACL, ACL injury recurrences, and sustaining ACL injuries during the last 6 weeks of the playing season.

Following on from the PEP, the most publicised preventive exercise programme is the "11+", developed by the FIFA Medical Assessment and Research Centre (F-MARC) (Bizzini, Junge, & Dvorak, 2013b; Grooms et al., 2013; Soligard et al., 2008). The "11+" represents a reformat of the "11", which had demonstrated equivocal effects on injury risk in both female (Steffen, Myklebust, Olsen, Holme, & Bahr, 2008b), and male soccer players (Junge et al., 2011; van Beijsterveldt et al., 2012). Conclusions from studies that had evaluated the efficacy of the "11" identified that low compliance to use, due to a lack of progression, variation, or sport-specificity in the exercises, was a likely reason for the lack of any preventive effect on injury risk. The "11+" was designed to overcome the limitations of the "11" by including more sport-specific agility and running exercises at intervals, as well as progressing the difficulty of exercises (Grooms et al., 2013). The "11+" protocol consists of three phases: phase one is comprised of 6 moderately-paced running-based drills, followed by 6 exercises that specifically target lower extremity strengthening, balance, and neuromuscular control and stabilisation strategies. The

final component consists of 3 higher intensity, sport-specific running drills with the addition of evasion manoeuvres. Once familiarised with the protocol, it would be possible to complete within 20 minutes. Soligard et al. (2008) first investigated the efficacy of the "11+" in adolescent female community soccer players across an 8-month playing season. Results revealed favourable reductions in overall lower limb injury risk (RR=0.68, 95% CL 0.48-0.98) with particularly notable reductions in overuse injury risk (RR=0.47, 95% CL 0.26-0.85) and severe injury risk (RR=0.55, 95% CL 0.36-0.83). The "11+" has also been applied successfully in male soccer, with Grooms et al. (2013) establishing that the programme resulted in a 72% reduction in overall injury risk (RR=0.28, 95% CL 0.09-0.85). In addition, Longo et al. (2012) demonstrated that the "11+" could prevent injuries in male basketball players over a 9-month playing season. The "11+" reduced overall injury risk by 56% (RR=0.44, 95% CL 0.17-0.60), with particular reductions also noted in lower extremity injury risk (RR=0.49, 95% CL 0.19-0.84) (Longo et al., 2012).

Similarly to the PEP programme, the "HarmoKnee" preventive programme specifically targets acute knee injuries in adolescent female athletes. The "HarmoKnee" protocol features 5 parts: warm-up, muscle activation, balance, strength, and core stability. Kiani et al. (2010) investigated the use of the "HarmoKnee" programme in a sample of female community soccer players. Over the course of one 9-month study period, 94% of the players performed the warm-up at more than 75% of the training sessions. The risk of suffering an acute knee injury was reduced by 77% (RR=0.23, 95% CL 0.04-0.83), whilst non-contact knee injury risk was reduced by 90% (RR=0.10, 95% CL 0.00-0.70) in teams that used the "HarmoKnee" programme compared with a cohort of teams that continued with their regular practices. Another similarly targeted programme, the Knee Injury Prevention Programme (KIPP), was developed and evaluated by LaBella et al. (2011) in female soccer and basketball players over one playing season. The KIPP contained progressive strengthening, balance, plyometric, and agility exercises, with the protocol being performed in 80% of sessions. Overall injury risk decreased by 56% (RR=0.44, 95% CL 0.26-0.76), whilst overuse injury risk was also reduced (RR=0.35, 95% CL 0.18-0.69) in teams that used the KIPP programme compared with control teams that used their typical warm-up protocols.

Away from sporting populations, Coppack et al. (2011) investigated the use of a strength and stretching-based intervention, the Anterior Knee Pain Prevention Training Programme (AKP PTP), in male and female military recruits over a 14-week period. Recruits performed the protocol during 7 structured, supervised sessions per week. The risk of anterior knee pain was reduced by 75% in recruits who were randomly allocated to receive the AKP PTP against those who performed a usual warm-up (RR=0.25, 95% CL 0.13-0.52).

Certain themes emerged when comparing the programmes in Table 4.1. All of the protocols incorporated a variety of training methods, of which targeted resistance training, perturbation and plyometric activities, and sport-specific agility exercises were commonly included. A meta-analysis of the efficacy of preventive exercise programmes conducted by Lauersen, Bertelsen, and Andersen (2014) identified that protocols with a specific focus on strength and proprioception led to substantial reductions in overall injury risk, as did multifaceted protocols. Based on these findings, preventive exercise programmes may achieve greater preventive effects on injury risk if they comprise a variety of training methods, with resistance and perturbation training as primary components. In addition to encompassing a variety of exercises, preventive exercise programmes may also need to progress in difficulty and/or repetition volume to provide a sufficient stimulus and maintain compliance among players. This was given as a reason by Steffen and colleagues (2008b) when explaining the lack of a preventive effect with the FIFA "11" programme. The authors also mentioned that greater provision of sport-specific activities may be required to maintain sufficient compliance (Steffen et al., 2008b). Given the subsequent changes that brought about the reformatted "11+" and the notable reductions in injury risk with increased compliance when the "11+" was evaluated, it would seem that these characteristics may be important across all programmes to maintain adequate compliance to using a preventive exercise programme.

To encourage programme compliance, it may be preferable to highlight any other salient benefits of adopting a preventive exercise programme into current practice, as well as explaining the rationale for the training methods to prospective adopters. In particular, demonstrating that performing a preventive exercise programme as part of a warm-up may still provide the necessary effects of a "usual" physiological warm-

up could remove potential barriers to use. Bizzini et al. (2013a) investigated the physiological effects of performing the FIFA "11+" as part of a structured warm-up, revealing that performing the "11+" programme increased oxygen uptake (14%, 95% CL 5-22%) and core body temperature (1%, 95% CL 0.8-1.3%), whilst also enhancing lower limb dynamic balance (3%, 95% CL 2-4%), lower limb power (6%, 95% CL 4-9%), agility time (-1%, 95% CL -1.5 to -0.5%), and linear sprint time (-2%, 95% CL -3 to -1%). By extension, it is possible that similarly devised protocols could replace aspects of existing warm-up practices whilst still enabling similar physiological and performance-related outcomes.

Assessing athletic performance-related changes associated with using preventive exercise programmes could inform on the possible physiological mechanisms by which preventive exercise programmes reduce injury risk, and may also be useful in promoting compliance with programme use amongst target users from an applied perspective (Impellizzeri et al., 2013; Steffen, Bakka, Myklebust, & Bahr, 2008a). For instance, both the FIFA "11+" and "HarmoKnee" exercise programmes have been shown to enhance hamstring and quadriceps strength indices (Brito et al., 2010; Daneshjoo, Mokhtar, Rahnama, & Yusof, 2012b, 2013a; Daneshjoo, Rahnama, Mokhtar, & Yusof, 2013b; Reis, Rebelo, Krustrup, & Brito, 2013), improve lower limb proprioception and dynamic balance (Daneshjoo, Mokhtar, Rahnama, & Yusof, 2012a; Impellizzeri et al., 2013) and increase measures of athletic performance such as agility, linear sprint speed and lower limb power in male soccer and futsal players (Daneshjoo, Mokhtar, Rahnama, & Yusof, 2013b; Reis et al., 2013). Lower limb movement control and muscle strength are important characteristics in enabling cutting and landing manoeuvres that are common across many field-based evasion sports, whilst also minimising the risk of injury attached to these events (Cochrane et al., 2010; Cochrane, Lloyd, Buttfield, Seward, & McGivern, 2007; Coughlan et al., 2014). Therefore, assuring programme deliverers that regularly using a preventive exercise programme can enhance athletic performance whilst reducing injury risk offers a means by which to promote compliance. Furthermore, a recent study investigated the acute effects of performing a single session of the FIFA "11+" programme on muscle activation patterns (Nakase et al., 2013), revealing elevated activity in the rectus abdominis and gluteus medius and minimus muscle groups of male participants that performed the "11+" programme compared with a control

group (at rest for a comparable duration). These findings may help to explain the enhanced lower limb movement control identified in other studies (Daneshjoo et al., 2012a; Impellizzeri et al., 2013). Movement control of the trunk and hip region along with hip abduction strength may also be important influences of lower limb stability and control (Hewett & Myer, 2011), and so preventive exercise programme may be best served to target hip abductor strength and trunk control in preventing lower limb injuries (Myer, Chu, Brent, & Hewett, 2008).

Of the variety of training methods included in preventive exercise programmes such as the FIFA "11+", a combination of static and dynamic stabilisation with plyometric exercises may be best placed to enhance lower limb muscle activation patterns and joint biomechanics. In support, studies have identified that separate protocols containing static and dynamic stabilisation exercises and plyometric exercises separately altered lower limb biomechanics whilst improving movement control (Myer, Ford, Brent, & Hewett, 2006; Myer, Ford, McLean, & Hewett, 2006). Elsewhere, Chimera, Swanik, Swanik, and Straub (2004) noted that hip adductor and abductor muscle groups displayed alterations in motor strategies during vertical jumping and sprinting following a period of plyometric training. Other studies have demonstrated that plyometric training, when incorporated into training or warm-up programmes, may reduce vertical landing forces by 17-18% (Vescovi, Canavan, & Hasson, 2008) and increase peak hamstring muscle power by 21-44% (Hewett, Stroupe, Nance, & Noyes, 1996).

Aside from lower limb balance and plyometric activities, targeted resistance training exercises have also been assessed in relation to the physiological mechanisms by which they may reduce injury risk. The Nordic Hamstring Extension is possibly the most well-studied resistance exercise related to injury prevention (Clark, Bryant, Culgan, & Hartley, 2005), with several studies supporting the efficacy of the Nordic Hamstring Extension in reducing the risk of posterior thigh muscle injuries in field-based team ball sports (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2008; Brooks et al., 2006; Engebretsen, Myklebust, Holme, Engebretsen, & Bahr, 2008; Petersen, Thorborg, Nielsen, Budtz-Jorgensen, & Holmich, 2011). Further studies have examined some of the mechanisms by which the Nordic Hamstring Extension may prevent hamstring muscle injuries, concluding that the preventive effects may

result from a combination of increasing hamstring muscle force (Clark et al., 2005; Potier, Alexander, & Seynnes, 2009) and lengthening the knee angle at which peak hamstring force occurs (Brockett, Morgan, & Proske, 2001; Brughelli & Cronin, 2007; Mjølsnes, Arnason, Østhagen, Raastad, & Bahr, 2004).

When considering the existing preventive exercise programmes and the training methods that they include, it is helpful to frame these characteristics against the current injury landscape in youth Rugby Union to gauge how a similarly devised programme may influence injury outcomes in young Rugby players. Epidemiological studies in youth Rugby, despite being of variable methodological quality, have typically shown that the upper and lower limb regions are at greatest risk of injury, and in particular the shoulder, knee, thigh, and ankle (Collins et al., 2008; Junge et al., 2004a; McManus & Cross, 2004). The shoulder and knee have also been shown to be at a high risk of severe injury types, such as fractures, joint dislocations, and ligament injuries (Bleakley, Tully, & O'Connor, 2011; Palmer-Green et al., 2013). The tackle situation is widely recorded as the leading injury mechanism in youth Rugby and has been implicated in as much as 41-60% of injuries, whilst non-contact injuries have typically been less common (Bleakley et al., 2011). Identification of potentially modifiable risk factors for injury are lacking in youth Rugby, with increasing age (Haseler et al., 2010), elevated playing levels (Palmer-Green et al., 2013), and participating in match-play as opposed to training identified as non-modifiable risk factors (Palmer-Green et al., 2015). These findings present several obstacles to developing a preventive exercise programme for use in youth Rugby. The high proportion of contact-related and upper limb injuries coupled with the low proportion of non-contact injuries and general lack of known modifiable risk factors highlight that simply applying an existing preventive exercise programme may not be successful in reducing injury risk, given that many existing programmes target non-contact related lower limb injuries. It is presently unclear if similar principles are applicable to a more contact sport-orientated setting, although the need to target specific injury types and susceptible body locations with training interventions has been recognised at elite playing levels within Rugby (Brooks et al., 2006; Meir, Diesel, & Archer, 2007). Therefore, developing a novel exercise programme that adheres sufficiently to sound scientific evidence (where available)

and valuable knowledge of the nuances in reducing injury risk in a contact sport could provide the best opportunity to affect injury outcomes.

4.3   Assembling a Technical Project Group

Following the review of the existing scientific evidence base, it was important to begin assessing the extent to which the information gathered from the review could be applied to a youth Rugby context. There is a requirement for multidisciplinary interactions to successfully develop and implement a preventive exercise programme, such as between prospective deliverers, researchers, and governing bodies, and so it was highly important to engage parties whose knowledge, attitudes, and activities could positively shape the development and implementation of the programme (Donaldson, 2010). From a practical perspective, achieving the dual goals of consulting with relevant stakeholders and coordinating the development of the programme was best-served by convening a multidisciplinary technical project group (TPG) to begin the process of developing the structure of the preventive exercise programme (February 2014) (Donaldson, 2010). The TPG comprised academic, sporting, and clinical expertise, containing researchers who had previously investigated the development and efficacy of preventive exercise programmes in other sports, medical practitioners working in adult and youth-level Rugby, and coaches with backgrounds in strength and conditioning and community-level Rugby provision. Ensuring that academic, sport, and clinical interests were represented in the TPG was crucial to creating an evidence-informed exercise programme that was acceptable to stakeholders and could be feasibly delivered. In addition to formulating the structure of the preventive exercise programme, observations were also sought from the TPG regarding logistical barriers to implementing the programme, with possible solutions discussed within the TPG. Table 4.2 outlines the logistical barriers and associated solutions highlighted by the TPG. Additional recommendations from the TPG centred on fashioning the method through which the exercise programme would be delivered, which stakeholder(s) would be ideally placed to deliver the programme, and what support materials would be required to aid key stakeholders in delivering the programme.

Table 4.2   Logistical barriers identified by the technical project group, with associated solutions that were discussed

	Barrier	Solution(s)
Time	12 weeks to implement the preventive training programme	- Identify if reduction in injury risk can be attained within 12 weeks - Incorporate concentrated period of use during pre-season period
	15-20 minutes to complete programme at each session	- Assess which training methods can help to reduce injury risk and be performed in the allocated time
	Programme should be performed as often as possible	- Ensure programme is compatible with training sessions and matches
Personnel	Limited experience and competence of programme deliverers	- Identify strategies to improve deliverers' self-efficacy and competence in delivering programme
	Unknown baseline physical capabilities of end beneficiaries performing the programme	- Pilot test the same programme content across all age groups (14-18 years) - Provide team-based progressions in exercise complexity and/or volume at regular intervals.
Environmental	Setting in which programme will be completed	- Specify that programme should be completed in an outdoor space with room enough for players to move around whilst running
	Equipment available when completing the programme	- Select exercises that require no additional equipment to perform
Organisational	Goals and priorities of programme deliverers in target population	- Demonstrate that completing the programme will not detract, and may contribute to achieving goals and priorities of organisation (injury prevention, performance enhancement) - Demonstrate that completing the programme may also aid technical skill development - Show that completing the programme brings similar benefits of a warm-up - Highlight that programme has potential to be implemented across other sports
	Current warm-up / additional strength & conditioning practices in target population	- Show that the programme can be implemented into existing warm-up - Establish that programme is not designed to replace, but supplement, existing strength & conditioning practices

Following a face-to-face meeting in February 2014, the TPG reached an agreement over the programme structure (see Figure 4.2). In line with the structures of existing preventive exercise programmes, the agreed programme structure was required to:

- Contain a variety of training methods (multifaceted).
- Progress exercises at regular intervals through a combination of increasing volume and/or complexity of exercises.
- Be completed within 15-20 minutes, once stakeholders were familiarised with using the programme.
- Include an introductory phase that could be used during the school Rugby pre-season period.

The research team subsequently began to select exercises and progressions to include within the programme following agreement by the TPG over the programme structure. Exercise inclusion was primarily decided with input from other preventive exercise programmes. In some cases, the evidence base for certain exercises was particularly strong, such as for the Nordic Hamstring exercise (Arnason et al., 2008; Brooks et al., 2006; Mjølsnes et al., 2004; Petersen et al., 2011), and the specified volume of repetitions could be adopted from an existing protocol (Soligard et al., 2008). In certain cases where evidence-based training methods for certain injury types were lacking in the literature or the baseline physical capabilities of the target population were unknown, the professional judgements of the TPG members were gathered. For instance, the upper limb is a common injury location within youth Rugby. However, literature evidence regarding whether and which exercises prevent upper limb injuries was scarce, given that other preventive exercise programmes had typically focused on lower limb injury prevention (Steffen et al., 2010). Therefore, the selection of exercises and progressions for the upper limb was largely decided by members of the TPG.

Based on previous experiences of developing preventive exercise programmes, members of the TPG identified that coaches would be best-placed to deliver the programme in a school Rugby environment. To support coaches in delivering the programme, TPG members recommended that the delivery method for introducing

the exercise programme should be in the form of a comprehensive, face-to-face workshop for coaches, which has been identified as a useful method in previous research (Steffen et al., 2013b). In line with other programmes such as the FIFA "11+", materials to support coaches in delivering the programme ought to include: a manual with specific details relating to the programme structure and execution of each exercise, and laminated cue cards detailing each programme phase and 2-3 salient cues for coaches to use with their players (Soligard et al., 2008). These measures were felt to be conducive to maximising coaches' self-efficacy and competence in delivering the exercise programme.
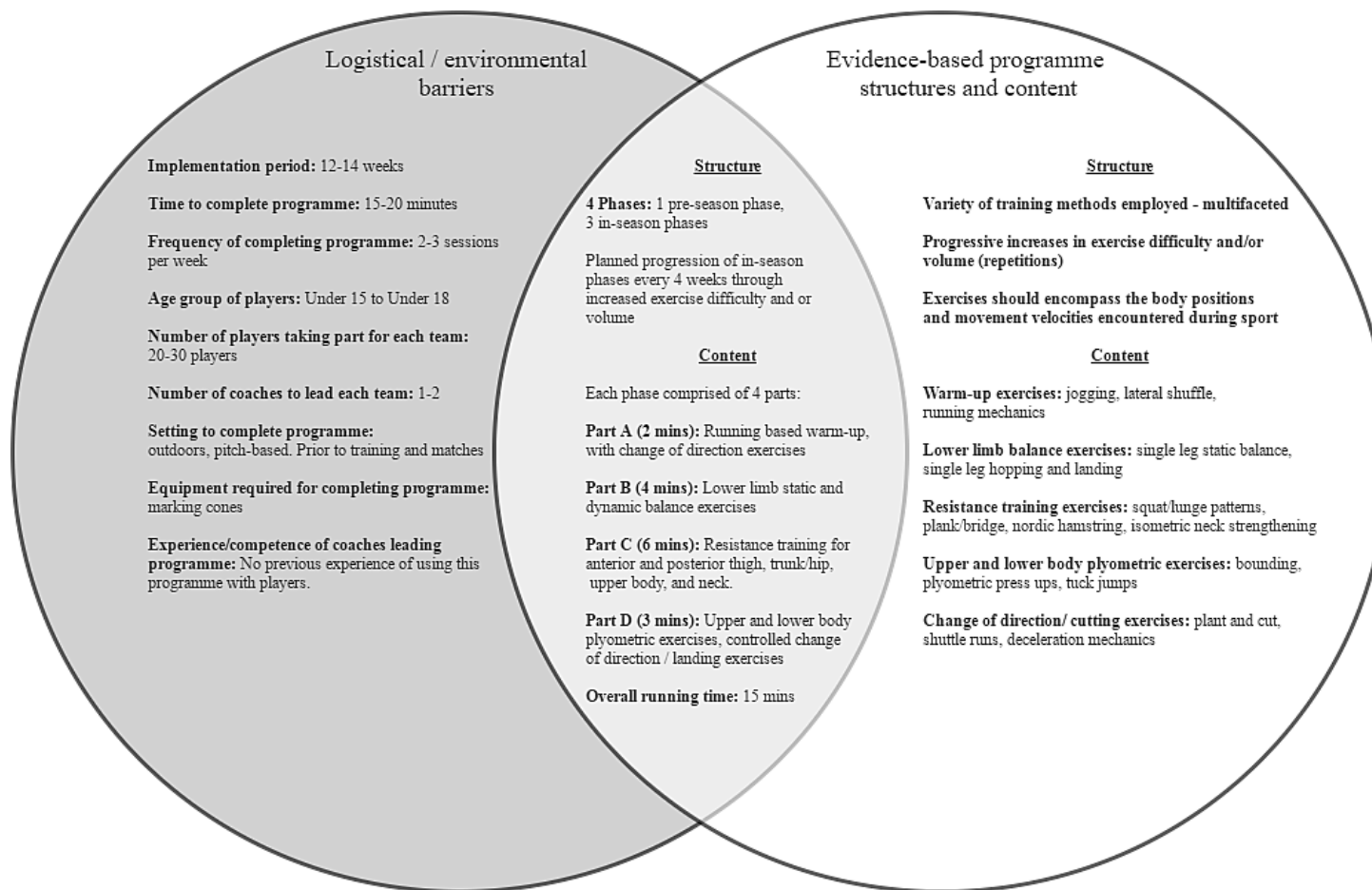
Figure 4.2   Development of the preventive exercise programme, with consideration for both logistical and environmental barriers to using the programme and the existing evidence base for preventive exercise programme structure and content.

The introductory workshop would focus on explaining the rationale and potential benefits behind the programme to coaches, such as preventing injury and enhancing athletic performance in players. The research team would also highlight that the programme was endorsed by the National Governing Body (Rugby Football Union) and developed with input from practitioners and academics involved in youth sport to improve coach buy-in. Another goal of the discussions between the research team and coaches would be to instil knowledge of when and where to perform the programme, as well as when to advance through the phases. The research team would also deliver a practical demonstration of leading the programme with a group of players under similar conditions to what coaches could expect. The research team would begin by explaining the programme rationale to players followed by providing 2-3 salient targeted cues (using the laminated cue cards) to enhance movement technique or correct errors as players performed each exercise. Coaches would also receive the programme support materials during the workshop. The support materials were intended to extend on the information that was exchanged during the workshop, whilst maximising the self-efficacy and competence of coaches who were going to be leading the programme.

4.4   Pilot testing the intervention and control exercise programmes

Once the structure and content of the preventive exercise programme had been agreed by the TPG, the next step was to pilot the programme within an appropriate context. This step was important for identifying whether the programme was acceptable to programme deliverers and players. Pilot testing also provided a useful opportunity to engage with programme deliverers and seek feedback about any changes needed to the programme's structure or content ahead of a more comprehensive roll-out and evaluation. The exercise programme was implemented in 6 teams (2 x under-15, 2 x under-16, 2 x under-18) across 2 schools during the 2014/15 Winter term (August-December 2014).

All coaches attached to the under-15, under-16, and under-18 teams attended a pre-study workshop in which they were instructed about how to implement the programme with their players, provided with support material for use during the study, and finally were provided with a practical demonstration of the programme by

the research team using a small group of players to recreate a likely scenario in which the programme would be ideally completed. Coaches were advised to use the programme as often as possible with groups of players, and were prompted as to when to advance the programme by the research team during the season.

There were several advantages to piloting the programme over the course of a season as opposed to during single sessions, not least that this closely reflected the intended everyday use (Donaldson et al., 2016b). An obvious advantage was that this would provide a useful opportunity for programme deliverers to feedback comprehensively on all aspects of using the programme, including:

- Experiences of progressing the phases of the programme in a specific time frame
- Becoming accustomed to using individual exercises
- Encountering logistic (e.g., timings, use prior to matches and training sessions) or environmental barriers (e.g., weather)
- Reporting programme modifications
- Interpreting programme support materials

4.5   Obtaining feedback from programme delivery agents

Of the two schools who piloted the programme during the 2014/15 winter term, one school did not implement the programme for the full trial period across any age groups and dropped out of the study due to reasons external to the programme, whilst the other school successfully implemented the programme across all age groups for the full trial period. Coaches at both schools were contacted and subsequently provided feedback on implementing the pilot programme to the research team (November 2014-January 2015).

Feedback was separated into three principal categories relating to: the programme structure and content, the coach the coaches' workshop, and the programme support materials. In relation to the programme structure and content, coaches were generally supportive of the programme as an initiative and felt that the content was generally appropriate to the players' physical development needs. It was generally felt that the programme was not sufficiently advanced in the early phases for the under-18 age group, but was sufficient for the younger age groups. In order to maintain

compliance with using the programme and hence provide a sufficient stimulus, coaches advocated that the programme should be modified between the age groups whilst still containing the same training methods. This feedback led to the programme phases being offset between each age group, such that the phase 3 of the under-15 programme was designed to be similar in difficulty to phase 2 of the under-16 programme, which in turn was similar to phase 1 of the under-18 programme (Figure 4.3). The TPG felt that this change would be sufficient to satisfy the programme deliverers whilst still maintaining an element of similarity between the separate programmes.

14/15 Pilot Programme format			15/16 Updated programme format		
Under 15	Under 16	Under 18	Under 15	Under 16	Under 18
↓	↓	↓	↓	↓	↓
Phase 1			→ Phase 1		
Phase 2			→ Phase 2	Phase 1	
Phase 3			→ Phase 3	Phase 2	Phase 1
Phase 4			→ Phase 4	Phase 3	Phase 2
				Phase 4	Phase 3
					Phase 4
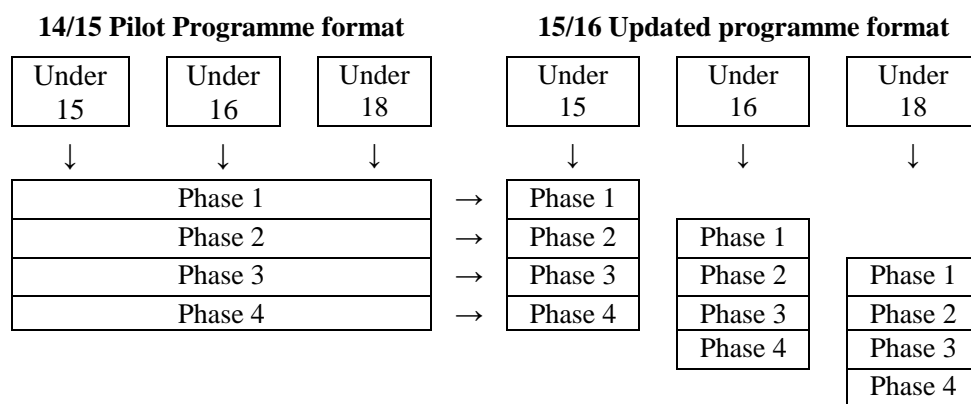
Figure 4.3   Changes to the progression sequence of the exercise programme, following pilot testing.

One coach raised the possibility of including resistance training targeted at the neck (cervical spine) region in the programme. This need was substantiated by the scientific literature, with studies indicating highly variable inter-individual neck strength profiles amongst youth Rugby players aged 11-18 (Hamilton et al., 2012), and that under-18 Rugby players were shown to have markedly lower neck strength profiles compared with adult Rugby players, despite having similar peripheral strength profiles (Hamilton et al., 2014). Including neck conditioning exercises within the programme may contribute to reducing neck strength mismatches between players, particularly in front row players given the associated positional demands of scrummaging. Following agreement between TPG members that neck conditioning exercises should be included in the programme, the next step involved seeking out an

existing neck muscle strengthening protocol that did not require additional equipment. However, few evidence-based protocols existed, and so international best practice was sought (Viljoen, 2009). It was decided that the neck conditioning exercises and associated progressions should be of similar difficulty across all age groups. The inclusion of the neck conditioning exercises meant that the volume of other exercises needed to be reduced to keep to the agreed time limit of 15-20 minutes to complete the programme. This was also in-keeping with the views of some coaches that the volume of certain exercises should be reduced to keep to the time frames. Other minor comments included coaches favouring the exclusion of performing the Nordic Hamstring Extension exercise prior to matches, as players had reported feelings of muscle soreness after using the exercise.

Coaches generally agreed that the pre-trial workshop was beneficial for them in implementing the programme with their players, and in particular the practical demonstration of the programme was regarded as a useful reference point to work from. Feedback relating to the programme support materials highlighted that the manual should include a rationale for the exercises in the programme in relation to injury prevention that coaches could relay to players. In addition, all coaches thought that the inclusion of filmed demonstrations of each exercise would be of value in future, especially when learning new exercises ahead of progressing to a new phase.

4.6   Conclusion

Documenting the steps that have been taken to develop preventive exercise programmes can be a useful approach in promoting these strategies amongst target groups, and may contribute to achieving consensus processes for the development of future programmes. However, detailed accounts of how preventive measures have been developed prior to evaluation remain scarce in the scientific literature. This chapter has outlined the stages that were followed in developing an evidence-informed, context-appropriate preventive exercise programme for use in schoolboy Rugby. Through a combination of assessing the existing literature, seeking expert opinion, and pilot testing the programme under realistic conditions, it has been possible to create a preventive exercise programme that balances scientific evidence with the views of subject experts and end users.

CHAPTER FIVE

The efficacy of a pre-activity Movement Control Exercise Programme to reduce injuries in Schoolboy Rugby Union: a cluster randomised controlled trial

5.1   Introduction

Based on current recommendations, sports injury prevention encompasses identifying and targeting priority injury types with appropriate, evidence-based preventive measures (Finch et al., 2013). Evidence-based preventive strategies in rugby have sought to prevent serious and catastrophic injuries through a combination of improving coaching and officiating standards (Brown et al., 2016b; Gianotti et al., 2009), and adjusting the playing laws around set piece events (Cazzola et al., 2015).

Musculoskeletal injuries are a common reason for time-loss from sport for adolescent rugby players (Archbold et al., 2015; Palmer-Green et al., 2013), whilst severe musculoskeletal injuries can also contribute to long-term disability and a compromised quality of later life if sustained during childhood (Maffulli, Longo, Gougoulias, Loppini, & Denaro, 2010; Maffulli, Longo, Spiezia, & Denaro, 2010). Conditioning the musculoskeletal system to tolerate external forces, through enhancing both strength and movement control, has been advocated to reduce injury risk (Emery, 2003; Gamble, 2008). Moreover, the use of pre-activity, multifaceted exercise interventions is supported by an evidence base across male participants in sports such as basketball (Longo et al., 2012) and soccer (Grooms et al., 2013; Owoeye, Akinbo, Tella, & Olawale, 2014; Silvers-Granelli et al., 2015). However, the injury pattern in rugby is typically different from many other team ball sports, with a greater frequency of upper body and contact-related injuries (Brooks & Kemp, 2008; Junge et al., 2004a). As a result, it is not clear whether introducing a targeted exercise programme can reduce musculoskeletal injury risk in youth rugby players.

The efficacy of preventive exercise programmes can be influenced by several factors; notably, how compliant players and coaches are to using the programme and how frequently the programme is performed (Sugimoto, Myer, Micheli, & Hewett, 2015; van Reijen, Vriend, van Mechelen, Finch, & Verhagen, 2016). Greater compliance to using preventive programmes has been associated with enhanced prophylactic effects (Hägglund, Atroshi, Wagner, & Waldén, 2013; Soligard et al., 2010; Steffen et al.,

2013a; Sugimoto, Myer, Bush, & Hewett, 2014b; Sugimoto et al., 2012). In addition, dose-response relationships have also been identified between programme use and injury prevention, although this relationship has only been assessed in relation to anterior cruciate ligament injuries in female sportspeople (Sugimoto, Myer, Barber Foss, & Hewett, 2014a; Sugimoto et al., 2016). Finally, a systematic review of preventive exercise programmes suggested that completing a programme 3 or more times per week optimised efficacy (Herman et al., 2012). Assessing the effects of compliance and dose can be useful in reinforcing the outcomes of intervention research and informing subsequent implementation attempts (Finch, 2006).

5.1.1 Aims of Chapter

This chapter aims to assess the efficacy of a pre-activity movement control exercise intervention to reduce the incidence and burden of rugby-related injuries in a schoolboy population, and to assess the influences of programme dose and compliance on injury outcomes.

5.2   Methods

5.2.1   Study Design and Setting

A cluster randomised controlled trial was conducted over one school playing season (August-December 2015) within independent school rugby teams in England. The study design was planned in accordance with the CONSORT statement (Schulz, Altman, & Moher, 2010), and the trial was registered prior to starting recruitment (Registration Number: ISRTCN13422001).

5.2.2.   Sample Size and Recruitment

Due to under-15 (U15), under-16 (U16), and under-18 (U18) age groups being involved in the trial, each school was treated as a unique cluster within which all teams were allocated to the same trial arm. This approach minimised the number of schools required to provide the necessary statistical power for the study whilst also reducing the risk of contamination between the trial arms. A priori sample size calculations were completed with the formula proposed by Hayes and Bennett (1999), using data collected from a previous study on match injury risk in a similar population of youth rugby players (Palmer-Green et al., 2013). These calculations revealed a minimum required sample size for each trial arm of thirteen schools to discern a 30% reduction in injury incidence rate between the trial arms. An additional seven school were recruited in each trial arm to account for possible attrition. In total, forty schools were recruited with the aim of retaining thirty-two schools upon the trial's conclusion. To be eligible to take part in the trial, schools were required to have on-site access to physiotherapists, nurses, or doctors who would assess and treat all rugby-related injuries sustained by players.

An initial internet search yielded 220 potentially eligible schools with listed contact details for at least one of the following staff members: Head teacher / Principal; teacher in charge of sport; or teacher in charge of rugby. This list of schools was randomised into groups of sixty schools, with each group sequentially contacted by the research team through a combination of trial invitation letters, emails, and finally telephone calls to senior members of school sports programmes. Eligibility to take part in the trial was assessed and confirmation of the school's participation in the trial was sought during telephone contact with school sports staff. This recruitment procedure was repeated through each group of sixty schools until the target sample of forty schools had

provided written informed consent from a member of the senior management team to participate in the trial. The sample was then randomly allocated to receive either the intervention or control exercise programme on a 1:1 ratio.

All U15, U16, or U18 players who participated in training or match-play at recruited schools during the winter term were eligible to participate in the trial. Coaches provided informed consent during an initial "coach the coaches" visit in the summer term preceding study commencement (see *5.2.5 Standardisation Procedures*). Informed assent was collected from players at a pre-season visit during which anthropometric data were also collected. A trial information letter and opt-out form was distributed to parents/guardians of all participants through each school's parental mailing system. Parents / guardians who wished to opt their child out of the trial were requested to complete the opt-out form and return to the school project manager, who would return this to the research team.

5.2.3   Blinding

The randomisation process at both the recruitment and allocation stages was completed by an individual who was independent of the research team to reduce the risk of introducing bias into the sample. Schools were blinded as to their allocation of trial arm, having been briefed that they would be receiving an exercise programme to be delivered by the coaches to their U15, U16, and U18 teams during the study period. The members of staff involved in the management of the study at each school were unaware of the two-arm study design.

5.2.4   The Programmes being trialled

In addition to maintaining usual training and match warm-up practices, schools were randomly allocated to receive either the intervention or the control exercise programme that coaches were instructed to use as often as practical. The rationale for the structure and content, as well as the process of devising both exercise programmes have been reported previously (see *Chapter Four*). Both exercise programmes were designed to be structurally indistinct from each other, with only the content differing. Incorporated within both programmes were 4 progressive phases, with progressions occurring through a combination of increased complexity and prescribed repetition volume of exercises. Both programmes began with a phase 1 element, which was to be completed

in the pre-season period (typically 1-2 week duration). Upon commencement of the school term in September 2015, the programmes were progressed to phase 2 for the first four weeks of the term, before progressing to phases 3 and 4 during weeks 5-8 and 9-12 of the term, respectively. This timing enabled players to master the exercises before being introduced to a more advanced phase. Progression of the exercises was undertaken at the team-level, with all players within the same age group teams completing the same exercises at the same time. Phase progressions were offset by age group (i.e., phase 3 of the U15 programme was similar in complexity to phases 2 and 1 of the U16 and U18 programmes, respectively) to maintain a sufficient and appropriate stimulus for the players. Both programmes were intended to take place during the first 20 minutes of each pitch-based training session and match warm-up. In both cases, the coach or associated member of staff in charge of each team acted as delivery agents.

The intervention exercise programme incorporated lower limb balance/perturbation training, targeted resistance training, upper and lower body plyometric training; and controlled rehearsal of sport-specific landing and cutting manoeuvres with verbal feedback and reinforcement of technique from the coach. The control exercise programme was derived from currently regarded best practice within schoolboy rugby, and included a running-based warm-up, dynamic stretching, controlled wrestling, mobility, and speed / change of direction-related drills (without the specific feedback instructions given in the intervention programme). The content within both the intervention and control programmes were categorised into 4 separate parts (Parts A, B, C, and D) to aid the structure of sessions and compliance reporting. A sample phase from the intervention exercise programme have been supplied for supplementary reference.

5.2.5   Standardisation Procedures

The research team visited all participating schools to conduct a pre-trial "coach the coaches" workshop (typically 1 hour duration). Between June and July 2015. This briefing introduced coaches to either the intervention or control exercise programme and data collection materials, and provided a practical demonstration of a programme session with a group of players. The practical demonstration of the programme entailed coaches observing a research team member leading a group of youth rugby players (U15, U16, or U18) through a session. Coaches across both trial arms received

identically formatted data collection and exercise programme materials. Programme materials included a filmed demonstration of the exercises (as a DVD), laminated cue cards (images and key coaching cues for each exercise), and a booklet containing information about completing individual exercises and the overall programme, for supplementary reference during the season. Instructions were relayed to coaches to use the programme materials, particularly the laminated cue cards during sessions, to assess movement execution in relation to the specified cues for each exercise, and to identify movements that could be improved. Coaches received electronic and paper copies of the weekly exposure report forms, which detailed team-based training and match exposure, as well as programme completion information. Coaches were instructed to complete the exposure form on a weekly basis (i.e., Monday-Sunday). Each school's designated school medical professional also received electronic and paper copies of the injury report forms at these meetings, with instructions to complete a report form for each new injury when a player included in the trial visited for treatment of a school rugby-related injury. Finally, informed consent was sought from all coaches to participate in the trial.

A further meeting was arranged at all schools during the pre-season period (August-September 2015) for members of the research team to collect informed assent and baseline anthropometric information (standing height, seated height, body mass) from all players involved in the trial.

5.2.6   Data Collection

The day-to-day management of the trial was co-ordinated between the research team, the school's nominated project manager (usually the teacher in charge of the sport or rugby programme), and the school medical staff. Coaches who oversaw the U15, U16, and U18 teams recorded their team's school match and training exposure, as well as programme compliance. School project managers oversaw their coaching staff's data collection procedures, and the research team oversaw and monitored all school project managers and school medical centres. Coaches and medical staff were instructed to prospectively record all relevant data to aid this process. A member of the research team visited every two to four weeks to retrieve the report forms from the project manager.

5.2.6.1 Exposure and Compliance Reporting

The definitions of reportable match and training exposures were adapted from the consensus statement for injury definitions and data collection procedures in Rugby Union (Fuller et al., 2007b). Reportable match exposures included:

"Play between teams from different schools, where the specified duration of match play or maximum number of players on the field at any one time were not shortened".

Reportable training exposures included:

"Team-based, pitch-based physical activities under the control or guidance of the team's coaching staff that are aimed at maintaining or improving players' rugby skills".

Match and training exposure was captured on the same weekly exposure report form. Match exposure information included opponent, result, and a team list of players participating in each fixture. Training exposure information included the length of each training session (in minutes) and the number of players who took part in each training session. In cases where multiple fixtures were played in a weekly period, a second weekly report form was completed with the match information of the second fixture. Coaches were also responsible for recording on the weekly report form if they had completed their allocated programme with their team during each exposure, and which parts (A, B, C, and D) of the programme were performed. Programme compliance indicated the proportion of programme parts that were completed at the team level across all exposures.

5.2.6.2 Injury Reporting

A reportable injury was defined as:

"Any physical complaint sustained during a reportable school rugby exposure which leads to a player being unable to take a full part in any planned physical activity for greater than 24 hours after infliction of the index injury."(Fuller et al., 2007b)

Coaches started the injury reporting process by logging the date on which an injury occurred, the injured player's identity and playing position, and the event leading to

injury. Injured players then visited the medical staff for the injury to be treated. The medical staff recorded the injured body location and an injury diagnosis. Recording the injury location and diagnosis aligned with the first two levels of the Orchard Sports Injury Classification System (Version 10) (Rae & Orchard, 2007). The coach made a note on the injury report form of the return-to-play date for each injured player (i.e., date of full participation in training and considered ready for match selection). A member of the research team visited schools periodically (2-3 week intervals) during the study period to retrieve completed report forms and to discuss study progress, but not to promote compliance or fidelity with using the programmes.

5.2.7 Statistical Analyses

Statistical Analyses were undertaken with IBM SPSS Statistics (Version 22.0 for Windows, IBM Corporation, Armonk, NY, USA). Trial arm comparisons were made across baseline variables (age, anthropometric characteristics, and maturity timing) using linear and logistic regression models.

The effects of exercise programme on match-derived injury measures were analysed on intention-to-treat and per-protocol bases. Intention-to-treat analyses compared injury measures between the trial arms for all teams that provided injury and exposure data, regardless of returning complete programme compliance or dose data. Per-protocol analyses considered the effects of exercise programme on injury measures in teams who completed their allocated exercise programme at 3 or more sessions per week on average during the trial period, which represented a threshold for optimal compliance based on previous findings (Herman et al., 2012). Summary injury measures included incidence (injuries /1000 player-hours) and burden (days lost /1000 player-hours). Rate ratios (RR) and 90% confidence limits (90% CL) for injury incidence and burden were generated from trial arm comparisons, with the control arm serving as the reference category for comparisons, where applicable.

Per-protocol analyses were also conducted to assess the effects of intervention-only programme dose and compliance on injury. Firstly, teams were grouped into those that had completed the intervention exercise programme at three or more sessions per week on average during the study period, and those that had completed the intervention exercise programme less than three times per week on average during the study period.

Comparisons were then made between the two groups across overall match injury and contact-related injury measures. Secondly, the effects of compliance to using the intervention exercise programme on overall match injury and contact-related injury values were also analysed. Overall compliance was calculated as the product of coach compliance (proportion of programme parts A, B, C, and D that were completed) and player compliance (proportion of total number of players that completed the exercise programme parts). Teams were ranked by overall compliance and stratified into tertiles, with separate comparisons made between the high-intermediate and high-low compliance groups.

All analyses were conducted using generalised linear modelling with a Poisson distribution, a log-linear link function, and offset for hours of exposure. Inferences regarding the effects of exercise programme, intervention exercise programme dose, and intervention exercise programme compliance were assessed against a pre-defined smallest worthwhile effect in injury outcome, using a spreadsheet for deriving a confidence interval and clinical inference from a p-value (Hopkins, 2007). The smallest worthwhile effects favouring the intervention and favouring the control were given as RR=0.90 (i.e., a 10% reduction) and RR=1.11 (i.e., an 11% increase), respectively (Hopkins, 2010). Effects were classified as *clear* if the percent likelihood that the true effect favoured the intervention (i.e., RR below 0.90) was greater than 25%, and the odds ratio between benefit and harm was greater than 66 (i.e. if the likelihood of effect favouring the intervention was 25% and the likelihood of effect favouring the control was less than 0.5%), otherwise the effect was deemed *unclear*. Effects were qualified against probabilistic terms from the following scale: <0.5%, most unlikely; 0.5-5%, very unlikely; 5-25%, unlikely; 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; >99.5%, most likely (Batterham & Hopkins, 2006).

5.3   Results

From a target population of 220 potentially eligible schools that were contacted for recruitment, 40 schools (118 teams, 3,188 players aged 14-18 years) consented to participate in the trial and were randomly allocated to the intervention or control group (Figure 5.1). Nine schools and 35 teams dropped out of the trial, leaving the final study sample for analysis of 31 schools, 83 teams, and 2,452 players (intervention, 17 schools, 44 teams, 1,325 players; control, 14 schools, 39 teams, 1,127 players). Dropout rates

were slightly higher in the control arm than the intervention arm (team dropout: 33% vs. 27%; player dropout: 27% vs. 19%).

5.3.1   Player Characteristics

The mean age of the overall cohort was 15.9 ± 1.1 years, mean standing height was 177 ± 7 cm and mean body mass was 73.6 ± 13.0 kg (Table 5.1). Twenty-nine percent of players were estimated to be less than 1-year post-peak height velocity (512 players), whilst the remaining 71% of players were adjudged to be more than 1-year post-peak height velocity (1,228 players). *Trivial* and *unclear* effects were detected between the trial arms for players' age, standing height, body mass, and the distribution of players by maturity timing, with these variables not being considered as potential confounders in further analyses.
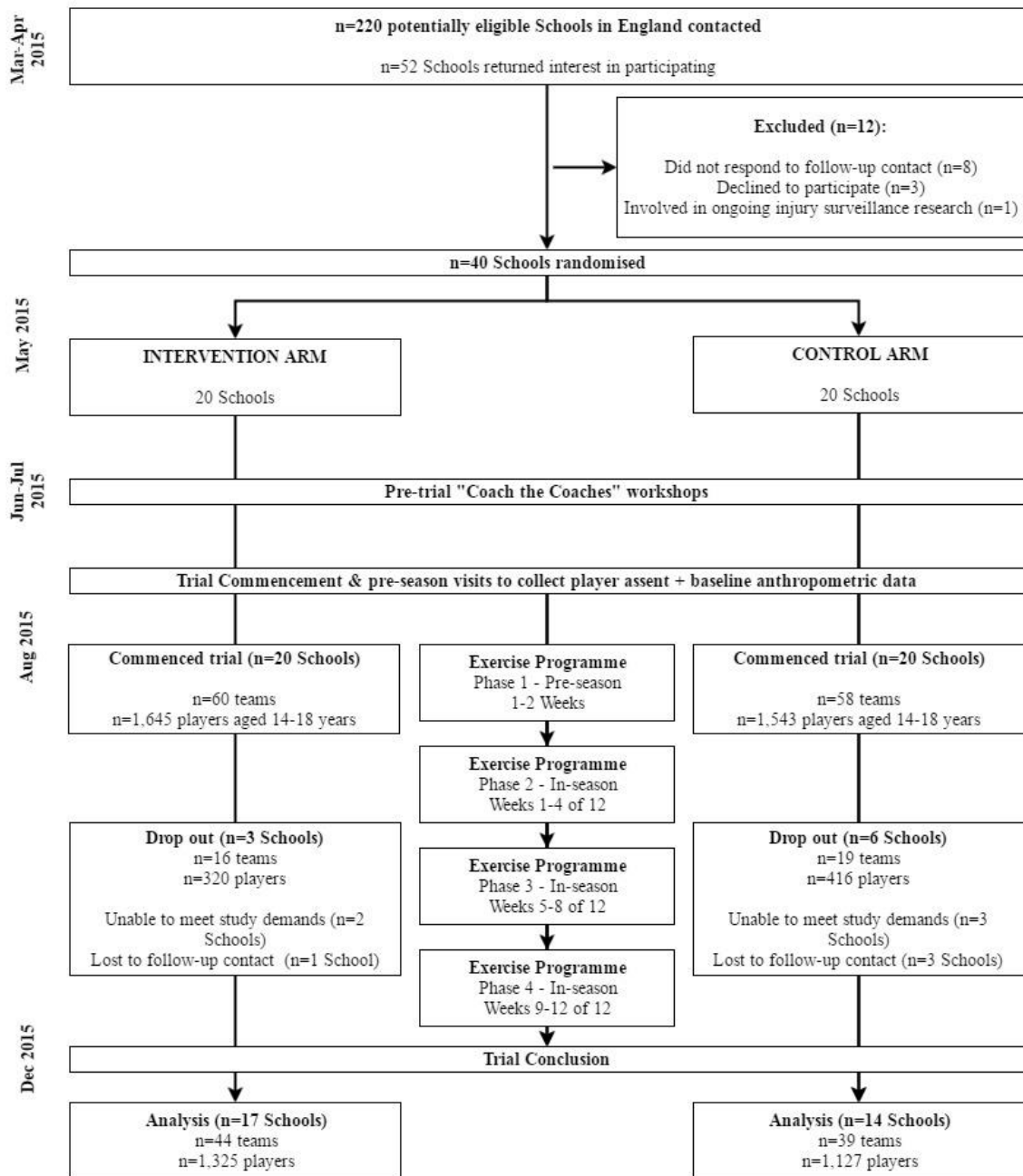
Figure 5.1   Flow diagram presenting the recruitment and retention of participants through the study

Table 5.1   Summary and comparisons of player characteristics between trial arms (n=2,452)

Trial Arm	Intervention	Control	Effect Size* (90% CL)	(% higher | trivial | lower) † Inference
Age (years)	16.0 ± 1.2	15.9 ± 1.1	0.06 (0.00-0.14)	0 | 100 | 0% *Most Likely Trivial*
Standing Height (cm)	177.4 ± 7.3	176.6 ± 7.5	0.11 (0.03-0.19)	4 | 96 | 0% *Very Likely Trivial*
Body Mass (kg)	74.7 ± 12.9	72.5 ± 13.1	0.17 (0.09-0.25)	27 | 73 | 0% *Possibly Trivial*
Maturity Offset (%)				
>1 year post-PHV	642 (71%)	586 (70%)	1.03 (0.91-1.16)	4 | 95 | 1% *Very Likely Trivial*
≤1 year post-PHV	261 (29%)	251 (30%)		

Data presented as mean ± SD or as raw frequency (%) where specified. PHV – Peak Height Velocity. *Effect sizes for Age, Standing Height, and Body Mass expressed as Cohen's d; effect size for maturity offset expressed as a proportion ratio (Hopkins, 2016). † Percentage likelihood of effect being higher or lower is analogous to effect favouring intervention or control, respectively.

5.3.2 *Exposure, Injury, and Compliance Characteristics*

Summary injury and exposure results between the trial arms are outlined in Table 5.2. The intervention cohort (n=17 schools, 44 teams) accrued 37,346 exposure-hours (match, 9,083, training, 28,263), with the control cohort (n=14 schools, 39 teams) reporting 32,375 exposure-hours (match, 6,855, training, 25,520). The intervention cohort recorded 233 match injuries (totalling 6,499 days lost) and 58 training injuries

(1,028 days lost), with the control cohort recording 208 match injuries (5,907 days lost) and 54 training injuries (1,150 days lost). Overall match and training injury incidence in the intervention cohort was 26/1000 hours (23-29) and 2/1000 hours (2-3), and in the control cohort was 30/1000 hours (27-34) and 2/1000 hours (2-3), respectively.

Complete exposure and compliance data was retrieved from 63 out of 83 teams (intervention, 32 teams; control, 31 teams). In teams who had provided complete compliance information, mean programme completion rate across both trial arms was close to twice per week (intervention, 1.9 sessions/week; control, 2.0 sessions/week). Twelve out of 63 teams maintained a mean weekly programme completion rate of 3 or more sessions (intervention, 7 teams; control, 5 teams). Mean coach compliance to the intervention exercise programme (proportion of available exposures in which the preventive programme was completed) was 69%, whilst mean player compliance (proportion of the total number of squad players who completed the programme at each exposure) was 83%. The mean overall compliance (product of coach and player compliance) to the intervention exercise programme was 59%. When intervention teams were split into tertiles, overall compliance in high compliance teams was 81% (n=11, mean completion rate=3.0 sessions/week), 56% in the intermediate compliance group (n=10, mean completion rate=2.0 sessions/week), and 31% in the low compliance group (n=11, mean completion rate=0.6 sessions/week).

Table 5.2   Summary descriptive statistics for injuries and exposure across the control (n=14 schools, 39 teams, 1,127 players) and intervention (n=17 schools, 44 teams, 1,325 players) trial arms

		Intervention (n=17 schools, 44 teams)	Control (n=14 schools, 39 teams)	Rate Ratio (90% CL)
Exposure Hours	Match	9,083	6,855	--
	Training	28,263	25,520	--
Injuries	Match	233	208	--
	Training	58	54	--
Days lost to injury	Match	6,499	5,907	--
	Training	1,028	1,150	--
Overall Match	Incidence	26 (23-29)	30 (27-34)	0.85 (0.61-1.17)
	Burden	715 (701-730)	862 (844-880)	0.83 (0.58-1.18)
Overall Training	Incidence	2 (2-3)	2 (2-3)	0.97 (0.52-1.81)
	Burden	36 (34-38)	45 (43-48)	0.80 (0.40-1.60)
Match Injury by Location				
Head/Neck	Incidence	9 (7-11)	13 (10-15)	0.72 (0.51-1.01)
	Burden	260 (252-269)	285 (274-296)	0.91 (0.55-1.51)
Upper Limb	Incidence	7 (6-9)	9 (7-11)	0.82 (0.51-1.31)
	Burden	229 (221-238)	345 (333-356)	0.66 (0.40-1.10)
Trunk	Incidence	2 (1-3)	2 (1-3)	0.90 (0.47-1.71)
	Burden	36 (32-39)	43 (38-47)	0.84 (0.35-2.01)
Lower Limb	Incidence	7 (6-9)	7 (5-8)	1.10 (0.7-1.72)
	Burden	190 (182-197)	189 (181-198)	1.00 (0.52-1.93)
Match Injury by Event				
Contact	Incidence	22 (20-25)	27 (23-30)	0.85 (0.60-1.19)
	Burden	607 (594-621)	689 (673-706)	0.88 (0.60-1.29)
Non-contact	Incidence	2 (1-3)	2 (1-3)	0.94 (0.50-1.77)
	Burden	77 (72-81)	121 (114-128)	0.63 (0.25-1.64)

Incidence values presented as injuries / 1000 hours. Burden values presented as days lost/ 1000 hours.

5.3.3 *Effect of exercise programme allocation on injury risk: Intention to treat analyses*

Intention-to-treat analyses on the effect of trial arm (intervention, 17 schools, 44 teams; control, 14 schools, 39 teams) revealed that overall match injury measures were reduced by 15-17% in the intervention group, although effects were *unclear* (Incidence RR= 0.85, 90% CL 0.61 to 1.17; Burden RR= 0.83, 0.58 to 1.18) (Figure 5.2). Reductions of 12-15% were also noted for contact-related injuries in the intervention group, although these effects were also *unclear* (Incidence RR= 0.85, 0.60 to 1.19; Burden RR= 0.88, 0.60 to 1.29). Clear beneficial effects favouring the intervention programme were noted for head/neck injuries (Incidence RR= 0.72, 0.51 to 1.01, *likely favours intervention*), upper limb injuries (Burden RR= 0.66, 0.40 to 1.10, *likely favours intervention*), and concussion (Incidence RR= 0.71, 0.48 to 1.05, *likely favours intervention*).

5.3.4 *Effects of programme dose and compliance on injury risk: Per-protocol analyses*

Per-protocol trial arm comparisons (intervention, 4 schools, 7 teams; control, 3 schools, 5 teams) revealed that teams who completed the intervention programme at 3 or more sessions per week suffered 72% fewer overall match injuries (Incidence RR= 0.28, 0.14 to 0.51, *most likely favours intervention*), 72% fewer contact-related injuries (Incidence RR= 0.28, 0.14 to 0.56, *most likely favours intervention*), 50% fewer days lost to contact injuries (Burden RR= 0.50, 0.21 to 1.18, *likely favours intervention*), 81% fewer upper limb injuries (Incidence RR= 0.07 to 0.50, *most likely favours intervention*), 70% fewer lower limb injuries (Incidence RR= 0.30, 0.10 to 0.92, *likely favours intervention*), and 59% fewer concussions (Incidence RR= 0.41, 0.17 to 0.99, *likely favours intervention*) than teams who completed the control programme at 3 or more sessions per week.

Subsequent per-protocol analyses conducted within the intervention arm indicated that teams typically completing the intervention programme at 3 or more sessions per week (4 schools, 7 teams) suffered 39% fewer match injuries and 48% fewer days lost to match injuries compared with teams typically completing the intervention programme at less than 3 sessions per week (10 schools, 25 teams) (Incidence RR= 0.61, 0.42 to 0.88, *very likely favours ≥3 completions per week;* Burden RR= 0.52,

0.29 to 0.93, *likely favours ≥3 completions per week*). In addition, teams completing the intervention programme at 3 or more sessions per week suffered 42% fewer match contact injuries and 55% fewer days lost to match contact injuries than teams completing the intervention programme at less than 3 sessions per week (Incidence RR= 0.58, 0.41 to 0.82, *very likely favours >3 completions per week*; Burden RR= 0.45, 0.25 to 0.82, *very likely favours >3 completions per week*). Effects of intervention programme dose were *unclear* for upper limb injuries, lower limb injuries, and concussion.

Several beneficial effects were noted for high compliance teams when compared with intermediate compliance teams (data not shown). High compliance teams suffered 43% fewer match injuries and 38% fewer days lost to match injuries than intermediate compliance teams (Incidence RR= 0.57, 0.38 to 0.85 *very likely favours high compliance*; Burden RR= 0.62, 0.37 to 1.03, *likely favours high compliance*). In addition, high compliance teams suffered 44% fewer contact injuries and 41% fewer days lost to contact injuries than intermediate compliance teams (Incidence RR= 0.56, 0.37 to 0.85, *very likely favours high compliance*; Burden RR= 0.59, 0.34 to 1.02, *likely favours high compliance).*
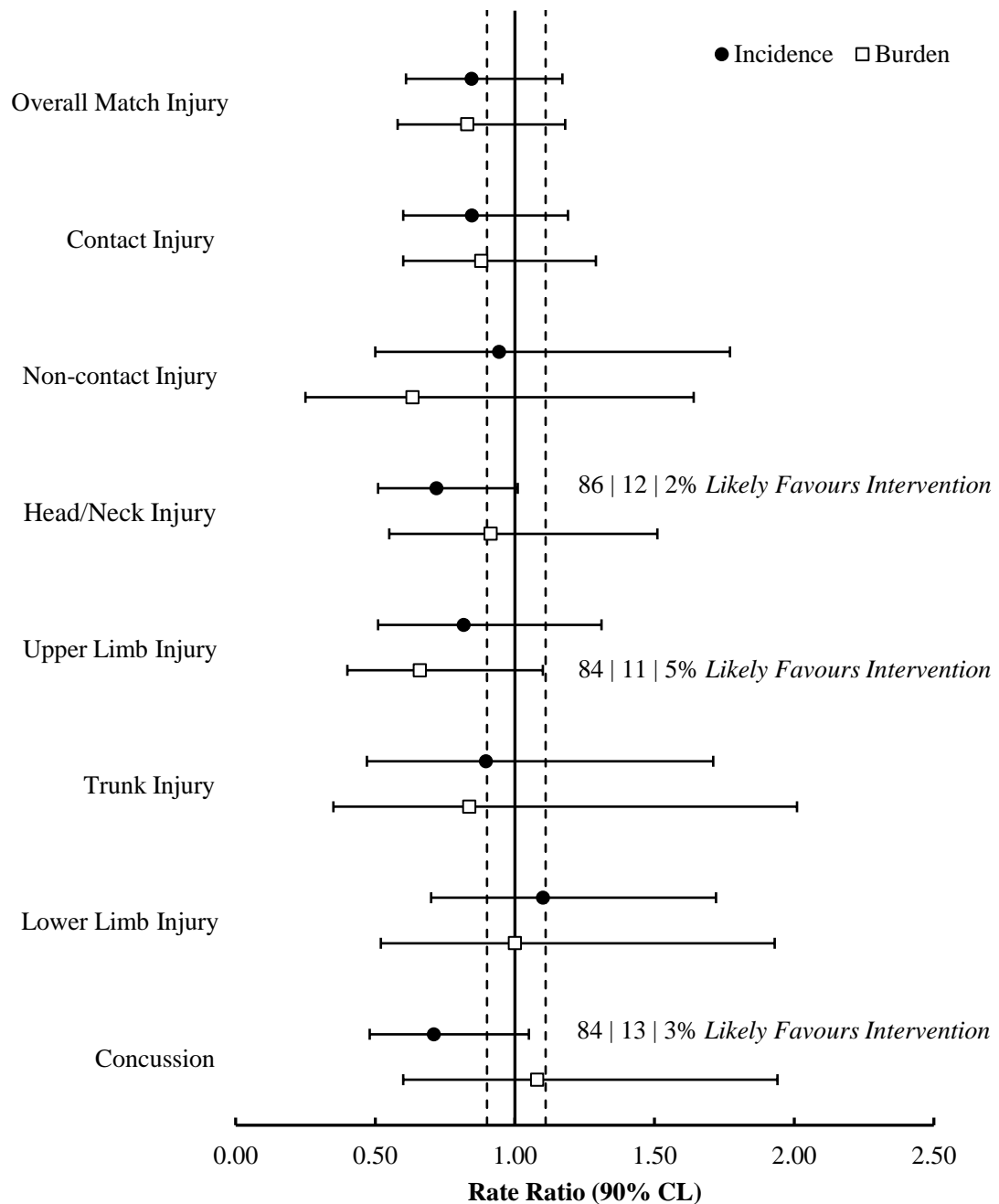
Figure 5.2   Forest plot illustrating the results of intention to treat analyses for effects of trial arm on injury measures (n=31 schools, 83 teams). Data points represent RR of injury measures in the intervention arm relative to the control arm (reference group, RR=1.00). Dotted vertical lines represent thresholds for smallest worthwhile effects (RR= 0.90 and 1.11). Data labels represent % likelihood that each effect favours the intervention | is trivial | favours the control, for outcome variables that demonstrate a clear effect of trial arm allocation.
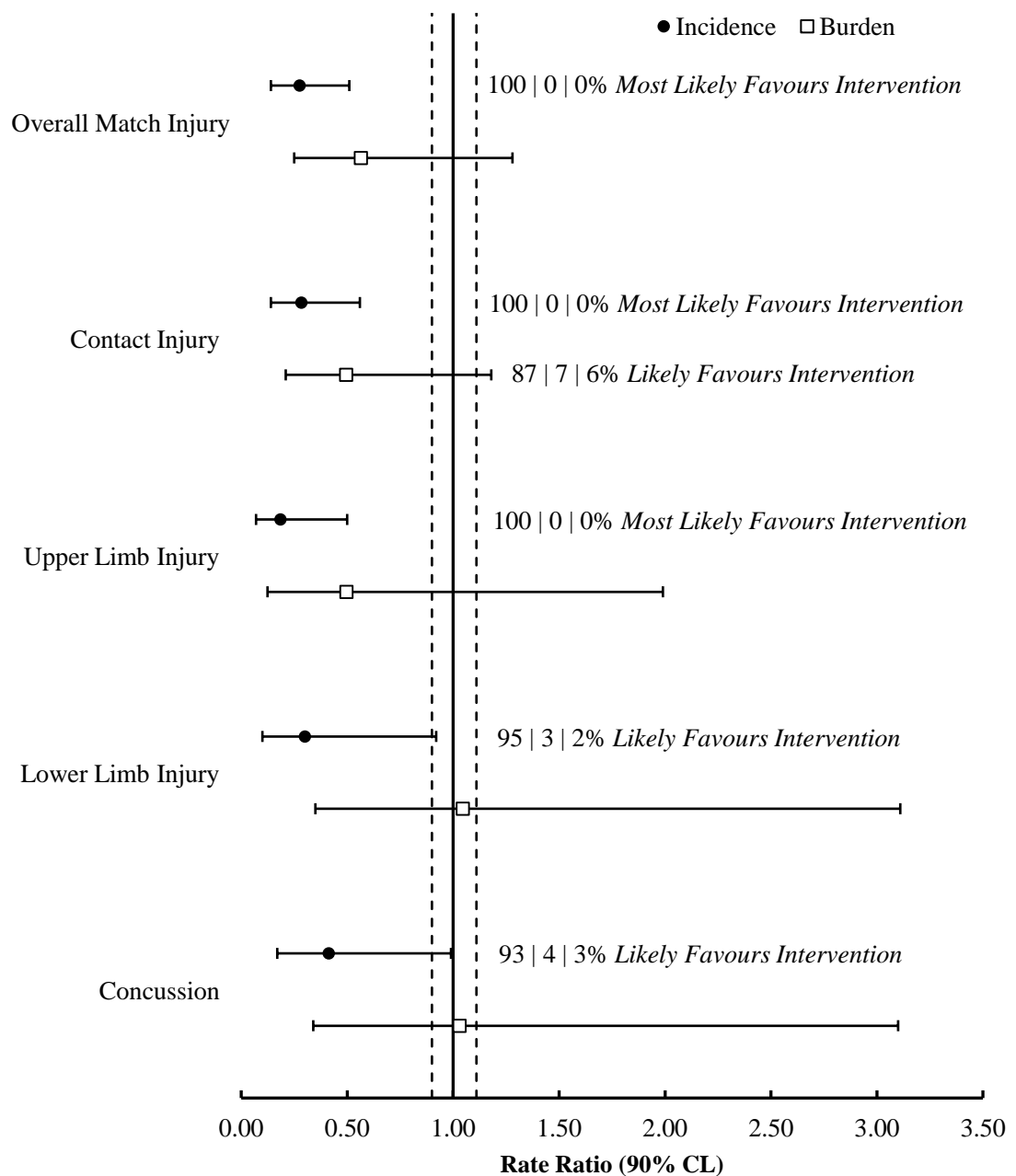
Figure 5.3   Forest plot illustrating the results of the per-protocol analyses for the effect of trial arm on injury measures in teams with a mean programme completion rate of more than 3 sessions per week (n=7 schools, 12 teams). Data points represent RR of injury measures in the intervention arm relative to the control arm (reference group, RR=1.00). Dotted vertical lines represent thresholds for smallest worthwhile effects (RR= 0.90 and 1.11). Data labels represent % likelihood that each effect favours the intervention | is trivial | favours the control, for outcome variables which demonstrate a clear effect of trial arm allocation.

Overall Match Injury Incidence	Rate (90% CL)	
<3 sessions/week (Ref)	28 (25-32)	
≥3 sessions/week	17 (12-23)	96 | 4 | 0% *Very Likely Favours ≥3 Sessions*
Overall Match Injury Burden	**Rate (90% CL)**	
<3 sessions/week (Ref)	796 (776-816)	
≥3 sessions/week	413 (385-441)	94 | 4 | 2% *Likely Favours ≥3 Sessions*
Match Contact Injury Incidence	**Rate (90% CL)**	
<3 sessions/week (Ref)	25 (22-29)	
≥3 sessions/week	14 (9-20)	98 | 2 | 0% *Very Likely Favours ≥3 Sessions*
Match Contact Injury Burden	**Rate (90% CL)**	
<3 sessions/week (Ref)	709 (690-728)	
≥3 sessions/week	320 (296-344)	97 | 2 | 1% *Very Likely Favours ≥3 Sessions*

Rate Ratio (90% CL)
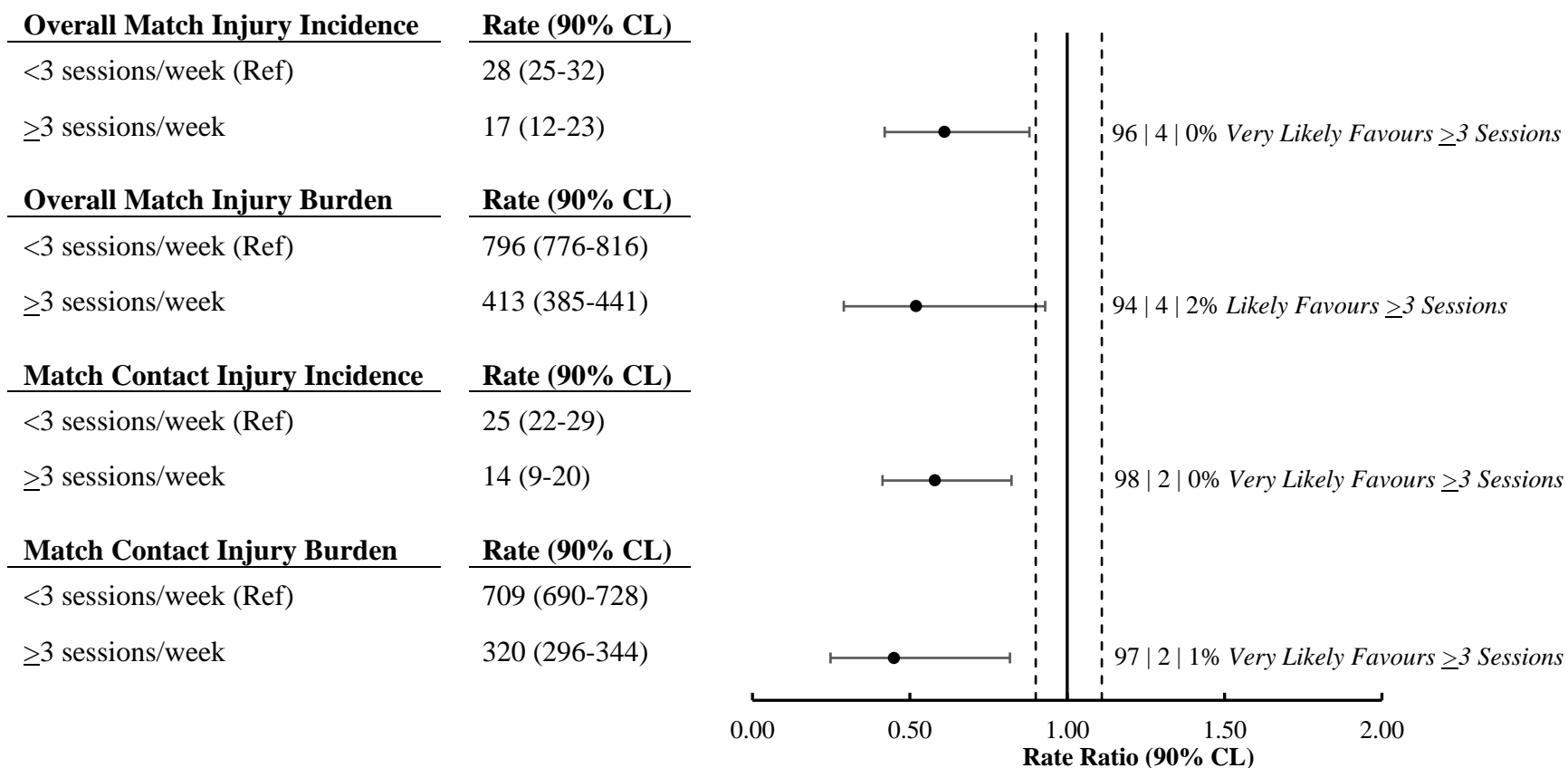
Figure 5.4   Forest plot illustrating the effect of intervention programme dose on injury measures (n= 14 schools, 32 teams). Data points represent RR of injury measures in >3 sessions per week group relative to <3 sessions per week (RR= 1.00). Dotted vertical lines represent thresholds for smallest worthwhile effect (RR= 0.90 and 1.11). Data labels represent % likelihood that each effect favours >3 sessions per week | is trivial | favours <3 sessions per week, for outcome variables which demonstrate a clear effect of programme dose.

5.4   Discussion

The purpose of this study was to determine the efficacy of a pre-activity movement control exercise programme for reducing injury in schoolboy rugby players, with a secondary aim of assessing the effects of programme dose and compliance on injury measures. Results of the intention-to-treat analyses indicated *unclear* effects of trial arm on overall match and contact-related injury, although clear effects favouring the intervention programme were noted in concussion incidence and upper limb injury burden. Per-protocol trial arm comparisons under conditions of a high programme dose (average $\geq$3 weekly programme sessions) revealed clear reductions of between 59-81% across injury measures in the intervention group compared with the control group. Moreover, a greater intervention programme dose was shown to reduce the incidence and burden of overall match injuries and contact injuries by 39-42% and 48-55%, respectively, when compared with lower intervention programme doses (average <3 weekly programme sessions).

Intention-treat analyses indicated that the effects of trial arm were *unclear* for overall match injury (Incidence RR= 0.85, Burden RR= 0.83) and match contact injury (Incidence RR= 0.85, Burden RR= 0.88). The 15% reduction in overall match injury incidence in this study is lower than the 41-56% reductions noted in other studies conducted in male basketball and soccer players, (Longo et al., 2012; Owoeye et al., 2014; Silvers-Granelli et al., 2015), which may be partly attributed to differences between definitions of reportable injuries, programme content, or the distribution of injury types and locations between the respective sports, i.e. proportion of non-contact lower limb injuries. However, effects favouring the intervention exercise programme were revealed for head/neck injury incidence (Incidence RR= 0.72) and concussion incidence (Incidence RR= 0.71). Sixty-two percent of reported head/neck injuries in the trial were attributed to concussion, and therefore the reductions in head/neck injury incidence were likely because of reductions in concussion incidence. Concussion is a priority for prevention across contact and collision sports due to heightened concerns over medium and long-term player health and welfare (Cross et al., 2015a; Fuller, Taylor, & Raftery, 2015). Despite the advances that have been made in managing concussed players and educating stakeholders on the risks of concussion (Fraas & Burchiel, 2016; Fuller, Kemp, & Decq, 2014), there is a need to identify effective means of primary prevention (Batten et al., 2016; Benson et al.,

2013). Thus, the substantially reduced concussion incidence across the intervention arm is a promising finding with regards to current efforts to reduce the risk of concussion.

Neck strength has been shown to be substantially lower in adolescent rugby players when compared with adults players with similar peripheral strength profiles (Hamilton et al., 2014). Increased concussion risk is associated with lower neck strength, highlighting this characteristic as a potentially modifiable intrinsic risk factor (Collins et al., 2014). Enhancing neck muscle strength may prevent concussion by improving the dissipation of impact forces transmitted to the brain (Patel, Shivdasani, & Baker, 2005; Schneider, Meeuwisse, Kang, Schneider, & Emery, 2013). Therefore, it is possible that the neck conditioning exercises in the intervention exercise programme contributed to the reduced concussion incidence via this mechanism. Impact anticipation is another potentially modifiable risk factor for concussion (Eckner, Oh, Joshi, Richardson, & Ashton-Miller, 2014; Mihalik et al., 2010). Enhancing neck strength could have a greater impact on concussions that arise from playing situations where players are able to activate the neck musculature prior to impact (Hendricks et al., 2016). Neck pain is a common physical complaint among young sportspeople participating in collision sports (Schneider, Emery, Kang, Schneider, & Meeuwisse, 2010; Shehata et al., 2009), and may be associated with increased concussion risk (Schneider et al., 2013). Given that acute and cumulative rugby exposure can adversely impact neck function (Lark & McCarthy, 2010; Lark & McCarthy, 2007, 2009), the neck resistance exercises may have contributed to preserving neck function during the playing season (Maconi et al., 2016), in turn leading to players suffering fewer concussions.

Upper limb injuries are common in contact sports and can also result in substantial time-loss in youth rugby players (Bleakley et al., 2011; Palmer-Green et al., 2013). Teams in the intervention trial arm suffered substantially fewer days lost to upper limb injuries than teams in the control arm (Burden RR= 0.66). Little is known about the underlying risk factors for upper limb injuries, and examples of evidence-based upper limb injury prevention are scarce (Steffen et al., 2010). Reduced glenohumeral rotation and rotator cuff muscle strength imbalances may be modifiable risk factors for shoulder injuries in rugby players (Ogaki et al., 2014). The intervention programme could have improved joint kinematics and force-handling capabilities

within the upper limb as a result of incorporating resistance and plyometric training of the upper body (Andersson, Bahr, Clarsen, & Myklebust, 2016; Niederbracht, Shim, Sloniger, Paternostro-Bayles, & Short, 2008), thus implying that reducing upper limb injury risk across youth contact sports is possible through improving upper limb strength, stability, and mobility.

The lack of any clear substantial effects for overall match and contact-related injuries following intention-to-treat analyses should be considered in the context of compliance and dose, which may have affected these outcomes. Coach compliance (i.e., proportion of programme parts that were completed) to the intervention programme was 69%, which was lower than previously reported in studies concerned with youth female soccer (77%-79%) (Hägglund et al., 2013; Soligard et al., 2010). However, average intervention programme dose in this study was higher (1.9 sessions per week) than previously reported in the same studies (1.3-1.4 sessions per week) (Hägglund et al., 2013; Soligard et al., 2010). Based on the intention-to-treat analyses, the level of compliance and dose that teams achieved in the intervention group may have been insufficient to produce a clear effect on overall match injuries. Greater effects of preventive exercise programmes may be realised if used at least 3 times per week over a period of three months or more (Herman et al., 2012). Per-protocol trial arm comparisons showed that intervention trial arm teams who regularly completed the programme more than three times per week suffered 72% fewer overall match injuries (Incidence RR= 0.28), 72% fewer contact-related injuries (Incidence RR= 0.28), 81% fewer upper limb injuries (Incidence RR= 0.19), 70% fewer lower limb injuries (Incidence RR= 0.30), and 59% fewer concussions (Incidence RR= 0.41) than control teams.

When per-protocol analyses were conducted within the intervention cohort, teams regularly completing the intervention programme over three times per week suffered 39% fewer match injuries (Incidence RR= 0.61), 48% fewer days lost to match injuries (Burden RR= 0.52), 42% fewer contact injuries (Incidence RR= 0.58), and 55% fewer days were lost to contact injuries (Burden RR= 0.45) than teams completing the intervention programme less than three times per week. Of note, when analyses were repeated across the control arm with the same criteria applied (i.e. mean programme completion rate less than/more than 3 times/week), no clear effects favouring the high dose sub-group (relative to the low dose sub-group) were

noted for overall match injury (Incidence RR= 2.02, Burden RR= 0.66) and match contact injuries (Incidence RR= 1.83, Burden RR= 0.75). Regularly performing a preventive exercise programme three times per week over a sustained period has been shown to improve markers for neuromuscular control and muscle strength in male soccer players (Impellizzeri et al., 2013). Therefore, these physiological changes may explain the enhanced effects noted in this study with a high dose of the intervention programme use compared with the control programme and a lower dose of the intervention programme. Previous studies that have identified a dose-response effect of preventive programmes have largely referred to specific high-risk injury types such as anterior cruciate ligament injuries (Sugimoto et al., 2014a). Findings of a dose-response effect on overall and contact-related injuries in this study present wider applications of the dose-response effect of preventive exercise programmes, and have the potential to inform subsequent implementation attempts through identifying a minimum effective dose in this population. Overall, the collective findings from the intention-to-treat and per-protocol analyses highlight that teams involved in contact sports can obtain benefit from using preventing exercise programmes, but more importantly, regular exposure of more than three times per week can result in substantial injury risk reduction in young rugby players.

Studies to evaluate the effects of compliance on preventive exercise programme efficacy have noted no clear differences in injury rates when teams were stratified by the proportion of sessions in which a programme was completed (i.e. team compliance) (Hägglund et al., 2013; Soligard et al., 2010). In this study, overall match injury incidence and burden were reduced by 38-43% (Incidence RR= 0.57; Burden RR= 0.62) for the high compliance group when compared with the intermediate compliance group, respectively. Contact injury incidence and burden were similarly reduced by 41-44% (Incidence RR= 0.56; Burden RR= 0.59) in the high compliance group relative to the intermediate compliance group. All effects were *unclear* for comparisons between the high and low compliance groups. When analyses were repeated for the control arm, all effects between the high compliance sub-group with either the intermediate or low compliance groups were unclear. On average, intervention teams in the high compliance group completed one-and-a-half-times as many weekly sessions as teams in the intermediate group (3.0 vs. 2.0 sessions per week) and over five-times as many weekly sessions as the low compliance group (3.0 vs. 0.6 sessions per week). The finding that effects were

unclear between the high and low compliance groups across all injury measures may reflect that coaches in the low compliance tertile were less likely to record injuries and direct injured players to the school medical centre for diagnosis and treatment (Soligard et al., 2010). Therefore, this may explain why injury values in the low compliance teams may have been underestimated as a result.

There were several limitations to this study that should be acknowledged. Firstly, the research team members that ran the pre-trial workshops and conducted pre-season visits were not blinded to the programme allocation for each school, creating potential bias between the two groups in terms of the processes followed and information disseminated at these workshops; this was mitigated through use of a unified workshop format. Secondly, individual player compliance was not monitored during the study. Results of previous studies have indicated that individual player compliance may be a more sensitive measure than team compliance in determining the influence of compliance on programme efficacy (Hägglund et al., 2013; Soligard et al., 2010), but puts considerable strain on coaches, and so wasn't feasible in this setting. Thirdly, it wasn't possible to validate coach compliance reports or to monitor exercise fidelity the quality of performing the exercises through unannounced visits or observations, given that schools have strict policies around access to premises. Consequently, the effects of fidelity with which teams used the programmes is uncertain, but may have mediated programme efficacy along with dose and compliance (Fortington et al., 2015).

Further work is required to understand the mechanistic basis by which the intervention exercise programme reduced injury outcomes, particularly in relation to the proposed effects of the programme on neck strength and function in reducing concussion incidence, as well as kinematics and force handling capacities in the upper limb. Determining efficacy is a crucial step towards effecting a public health impact of injury prevention measures in rugby, although results of this controlled trial alone are not sufficient to translate to reducing injuries in "real world" contexts (Hanson et al., 2014; Twomey, Finch, Roediger, & Lloyd, 2009). Further research is required to further understand the contexts into which the exercise programme would be implemented, as well as identifying what factors may facilitate or inhibit programme use (Finch, 2006). Studies should be directed to identifying what factors

could facilitate or inhibit teams from completing the intervention programme 3 times per week.

5.5   Conclusion

A preventive movement control exercise programme can reduce match injury outcomes in schoolboy rugby players when compared with a standardised control exercise programme, although in order to realise the greatest effects players should complete the programme at least three times per week. Notably beneficial effects of the preventive programme on upper limb injury burden and concussion incidence hold promising implications for the reduction of these priority injury types in youth rugby. In addition, these findings also widen the scope for the suitability of preventive exercise programmes in reducing musculoskeletal injury risk across a number of sports and a variety of injury categories. Maintaining high levels of compliance and completing the intervention programme three or more times per week were associated with numerous reductions in injury outcomes, which underlines the importance of accounting for these features when assessing the efficacy of preventive measures and the importance of formulating strategies to maximise compliance when implementing prevention programmes.

CHAPTER SIX

The association between psychosocial factors and compliance with a Movement
Control Exercise Programme amongst School rugby coaches

6.1   Introduction

There is an established evidence base to support the efficacy of preventive exercise
programmes in reducing musculoskeletal injury risk in tightly controlled settings
(Barengo et al., 2014; Bizzini & Dvorak, 2015; Herman et al., 2012; Hübscher et al.,
2010b), with recent meta-analyses estimating that programmes can reduce overall
injury risk by up to 39% (Incidence rate ratio (RR)=0.61, 95% confidence limit (CL)
0.48 to 0.77) (Thorborg et al., 2017) and lower limb injury risk by 36% (Incidence
RR=0.64, 95% CL 0.49 to 0.84) (Emery et al., 2015). In chapter five of this thesis, it
was also shown that a targeted preventive exercise programme could reduce days
lost to upper limb injury (Burden RR=0.66, 90% CL 0.40-1.10) and concussion risk
(Incidence RR=0.71, 90% CL 0.48-1.05) in youth rugby players when compared
with a standardised control exercise programme. Furthermore, higher intervention
programme doses (mean $\geq$ 3 sessions/week) led to reductions of 72% in overall
match injury risk (Incidence RR=0.28, 90% CL 0.14-0.51) and contact-related match
injury risk (Incidence RR=0.28, 90% CL 0.14-0.56) when compared with the same
dose of the standardised control exercise programme.

Compliance refers to the behaviour of an individual or group in following a
prescribed regimen for an intervention, relative to a fixed standard (McKay &
Verhagen, 2015; van Reijen et al., 2016). Several studies have found that higher
levels of compliance with using preventive exercise programmes are associated with
better injury reduction outcomes under tightly-controlled settings (Hägglund et al.,
2013; Soligard et al., 2010; Steffen et al., 2013a; Verhagen, Hupperets, Finch, &
Van Mechelen, 2011). Despite these documented improvements in reducing injury
risk that can come with increased use of preventive exercise programmes,
compliance rates to preventive exercise programmes have been relatively poor in
some settings (Emery et al., 2007; Steffen et al., 2008b), with little attention paid to

which determinants could influence compliance and how these determinants might be targeted (McKay, Steffen, Romiti, Finch, & Emery, 2014b; Soligard et al., 2010). Since complying with preventive measures will require some degree of behaviour change in many cases, one possible approach to enhancing compliance may be to focus on the psychosocial determinants of behavioural change among target populations (Van Tiggelen, Wickes, Stevens, Roosen, & Witvrouw, 2008; Verhagen et al., 2010). Applying behavioural change frameworks to injury prevention research can contribute to designing strategies that enhance desirable behavioural outcomes (such as compliance with using a preventive exercise programme) by identifying how antecedent psychosocial factors can influence behaviour (Keats, Emery, & Finch, 2012; McGlashan & Finch, 2010). However, this approach remains relatively novel and there is only a small body of literature supporting the application of behavioural change theories to the sports injury prevention field at present (McGlashan & Finch, 2010).

Coaches play an important role in shaping injury prevention behaviours among young athletes (Brown et al., 2016a; Chalmers, Simpson, & Depree, 2004; White et al., 2014), both directly through teaching safe sporting techniques (Gianotti, Hume, & Tunstall, 2010; Hendricks & Lambert, 2010) and indirectly by adopting and implementing preventive measures (Donaldson & Poulos, 2014; Verhagen et al., 2010). Although published examples are scarce, applying behavioural models to help with understanding the extent to which coach psychosocial factors can influence team compliance with a preventive exercise programme (as a behavioural outcome) may help to shape interventions to promote compliance, and in turn maximise the effects on reducing injury outcomes under controlled settings (McKay et al., 2014b; Sawyer et al., 2008; Twomey et al., 2009; White et al., 2014).

6.1.1 Aims of Chapter

The aims of this chapter are to describe selected baseline psychosocial factors and evaluate their association with compliance with using a movement control exercise programme amongst youth rugby coaches.

6.2 Methods

6.2.1 Study Design and Setting

This observational study was conducted as part of a cluster randomised controlled trial (RCT) that evaluated the efficacy of a movement control exercise programme to reduce injury risk in schoolboy Rugby Union during the 2015/16 school winter term (August-December 2015) (see *Chapter Five*).

6.2.2 Participants

This study sample was recruited from a target cohort of 118 coaches across forty independent schools in England that were recruited as part of the wider RCT. To be eligible to participate in this study, coaches had to be in charge of teams that were involved in the RCT and complete a baseline questionnaire at the pre-trial "coach the coaches" workshops conducted between June and July 2015. All coaches provided informed consent to participate in this study.

6.2.3 Data Collection

The research team conducted comprehensive coach-focused workshops across forty schools before trial commencement to train the coaches to use their allocated exercise programme. Coaches were invited to complete a paper-based questionnaire during the workshops, which was designed to capture information about coaching experience and history, perceptions and attitudes towards injury risk in youth rugby (Part one of questionnaire), and perceptions and attitudes towards using their allocated exercise programme (Part two of questionnaire). Part one of the questionnaire was delivered at the start of the workshop, with part two delivered at the end of the workshop. Questions were identically formatted for coaches across both trial arms of the RCT, with standardised polychotomous and five-point Likert scale responses to all questions.

The questionnaire was derived from Health Action Process Approach (HAPA) constructs (Schwarzer, 1992), and adapted from a questionnaire previously created

for use with youth soccer coaches (McKay et al., 2016; McKay et al., 2014b). Questions were re-phrased in some cases to more accurately reflect use amongst a population of rugby coaches, such as including injury types that are common among youth rugby players when asking coaches about their awareness of injury risk. The questionnaire underwent face validation by the research team prior to the start of the study.

During the playing season, coaches recorded compliance with using their allocated exercise programme at all their team's school rugby-related exposures (matches and pitch-based training sessions) using a weekly exposure report form. The intervention and control exercise programmes were comprised of four *parts* (A, B, C, and D) that contained different training methods, with coach compliance defined as the overall proportion of programme parts that were completed at the team level across all exposures (matches and pitch-based training sessions).

6.2.4   Statistical Analyses

Statistical analyses were conducted using SPSS (version 22.0 for Windows, IBM Corp, Armonk, NY, USA). All returned baseline questionnaire responses (parts one and two) were analysed descriptively, with relationships between antecedent psychosocial factors (risk awareness, outcome expectancy, and task self-efficacy) and intent to use the preventive exercise programme assessed via Spearman rank correlation coefficients (ρ) with a Bonferroni correction applied for multiple comparisons. Ninety percent (90%) confidence limits for correlation coefficients were calculated via non-parametric bootstrapping. Statistical significance for correlation coefficients was accepted at a Bonferroni-adjusted α level of $P<0.008$.

Data from coaches who had completed both parts of the baseline questionnaire and provided complete compliance data for the full duration of the study period were included in analyses to assess the relationship between psychosocial factors and coach compliance with the programme. Coaches were grouped by whether their compliance with the programme was equal to/above (i.e. high-compliance) or below (i.e. low-compliance) their respective trial arm mean compliance rates (intervention,

69%; control, 83%). Similarly, coaches were grouped by whether their questionnaire responses were equal to/above (i.e. high) or below (i.e. low) the median value for each psychosocial factor (risk awareness, outcome expectancy, task self-efficacy, intent to use the programme, coping self-efficacy, recovery self-efficacy, action planning). For psychosocial factors assessed by multiple questionnaire items (risk awareness, outcome expectancy, task self-efficacy, coping self-efficacy, and action planning), responses were pooled prior to calculating median values. The internal consistency for grouped psychosocial variables was assessed via Cronbach's Alpha (α). The relationship between each psychosocial factor and coach compliance was assessed by modelling the likelihood of being in the high-compliance group (i.e. compliance $\geq$ mean compliance) for coaches reporting high levels of a psychosocial factor (i.e. response $\geq$ median) relative to coaches reporting low levels of each psychosocial variable (i.e. response < median) (Hopkins, 2010). This approach employed a generalised linear model, with a binomial distribution and logit link function. Odds ratios generated from generalised linear models were then converted into proportion ratios (PR) to permit further magnitude-based inferential analyses (Hopkins, 2016). Effects sizes were assessed against smallest worthwhile effects on PR (smallest worthwhile reduction = 0.90, smallest worthwhile increase = 1.11) (Hopkins, 2007). Mechanistic effects were treated as *unclear* if the percentage likelihoods that the true effect could be substantially higher and substantially lower than the smallest worthwhile effects were both greater than 5%. Effect magnitudes were interpreted against the following probabilistic scale: <0.5%, most unlikely; 0.5-5%, very unlikely; 5-25%, unlikely; 25-75%, possibly; 75-95%, likely; 95-99.5%, very likely; >99.5%, most likely (Batterham & Hopkins, 2006).

6.3   Results

From the target population of 118 coaches, 82 coaches consented to participate in this study (figure 6.1). Seventy-six of the 82 coaches completed parts one and two of the questionnaire (intervention, 41 coaches; control, 35 coaches), with six coaches not completing part two of the questionnaire due to leaving before the workshop concluded (intervention, 4 coaches; control, 2 coaches). Twenty-two coaches did not

provide complete compliance data for the full study period or dropped out of the study (intervention, 13 coaches; control, 9 coaches). At the conclusion of the study period, 54 coaches had completed parts one and two of the baseline questionnaire and provided complete in-season programme compliance data (intervention, 28 coaches; control, 26 coaches).
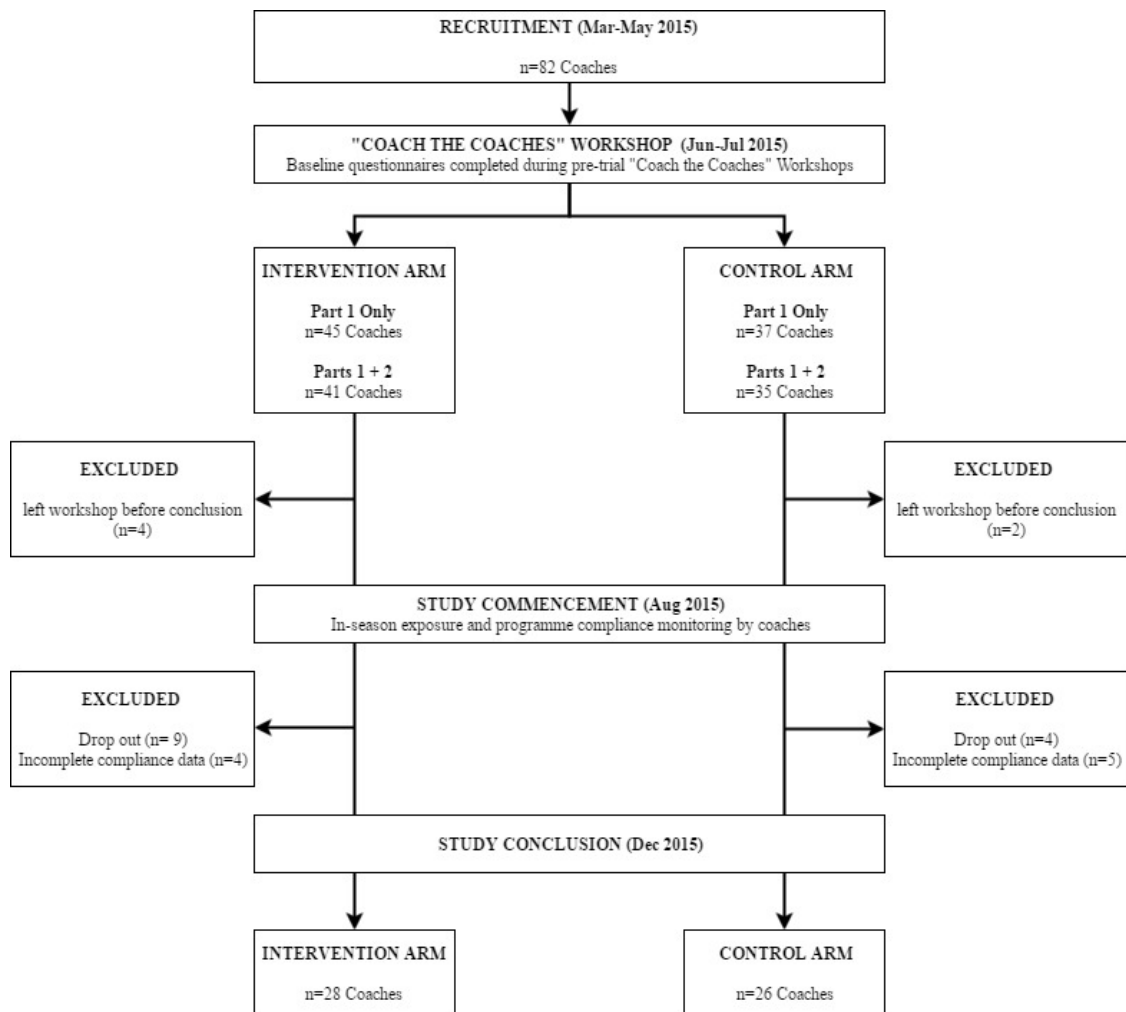
Figure 6.1   Flow diagram illustrating the recruitment and retention of coaches through this study

6.3.1   *Baseline Coach Characteristics*

The sample comprised 28 under-15 coaches, 21 under-16 coaches, and 33 under-18 coaches. Sixty-nine coaches (84%) had been coaching in youth rugby for longer than

5 years, with only one coach reporting a coaching experience of less than 1 year (1%). Seventy-four coaches (90%) possessed a formal rugby coaching qualification, whilst 39 coaches (48%) reported that they had previously used physical conditioning programmes to enhance athletic performance with their players (intervention, 23 coaches; control, 16 coaches).

6.3.2   Exercise Programme Compliance

Coaches in the intervention group (n=28) reported using the intervention exercise programme before 77% of matches (279 of 362 matches), and 80% of training sessions (600 of 750 training sessions). Coaches in the control group (n=26) reported using the reference exercise programme before 87% of matches (272 of 311 matches), and 90% of training sessions (599 of 663 training sessions). Table 6.1 presents the mean programme compliance rates between the trial arms and high/low compliance groups, accounting for the proportion of programme parts that were completed.

Table 6.1   Summary of overall programme compliance rates between trial arms and high/low compliance groups. Data presented as % (completed programme parts / total programme parts)

	Intervention	Control
Teams (*n*)	28	26
Match	65% (945/1448)	83% (1027/1244)
Training	71% (2124/3000)	83% (2202/2652)
Combined	69% (3069/4448)	83% (3229/3896)
High Compliance	(Overall compliance ≥ 69%)	(Overall compliance ≥ 83%)
Teams (*n*)	14	14
Match	92% (674/736)	90% (568/628)
Training	88% (1591/1800)	92% (1407/1528)
Combined	89% (2265/2536)	92% (1975/2156)
Low Compliance	(Overall compliance < 69%)	(Overall compliance < 83%)
Teams (n)	14	12
Match	38% (271/712)	75% (459/616)
Training	44% (533/1200)	71% (795/1124)
Combined	42% (804/1912)	72% (1254/1740)

Combined – Match and Training compliance rates

6.3.3   Injury Risk Awareness, Outcome Expectancies, and Task Self-Efficacy

Baseline coach injury risk perceptions and outcome expectancies are presented in tables 6.2 and 6.3, respectively. Internal consistency (Cronbach's α) for coach risk perceptions and outcome expectancies was α=0.60 and α=0.63, respectively. Most coaches (62%) regarded the overall injury risk in youth rugby to be "quite" or "very" high, and 29% of coaches believed injury risk was neither low nor high. Ninety-six percent (96%) of coaches believed concussion to be "quite" or "very" serious, with 79% of coaches regarding knee ligament injuries as "quite" or "very" serious, and 65% perceiving shoulder joint injuries to be "quite" or "very" serious. In contrast, 51% of coaches felt that thigh muscle injuries were "not at all" or "a little" serious. Eighty percent (80%) of coaches regarded muscle injuries as "quite" or "very" preventable, whilst 51% perceived ligament injuries and rugby-related injuries, in general, to be "quite" or "very" preventable.

Perceived task self-efficacy values are presented in table 6.4. Internal consistency for task self-efficacy was α=0.84. Ninety-eight percent (98%) of coaches felt that they understood their allocated exercise programme well enough to use it with their team, whilst 93% felt confident in their ability to lead the programme with their players.

Table 6.2   Baseline injury risk perceptions. Data presented as raw frequencies (%)

Perceived injury risk in youth rugby		Perceived severity of…				
	Response (%)		Knee ligament injury	Thigh muscle injury	Shoulder joint injury	Concussion
Very Low	1 (1)	Not at all serious	0	6 (8)	1 (1)	0
Quite Low	6 (8)	A little serious	2 (3)	33 (43)	1 (1)	1 (1)
Neither Low or High	22 (29)	Moderately serious	14 (18)	35 (46)	25 (33)	2 (3)
Quite High	45 (59)	Quite serious	41 (54)	2 (3)	44 (58)	20 (26)
Very High	2 (3)	Very serious	19 (25)	0	5 (7)	53 (70)
Total n	76		76	76	76	76

Table 6.3   Baseline injury prevention expectancies. Data presented as raw frequencies (%)

Perceived preventability of…			
	Muscle injuries	Ligament injuries	Rugby-related injuries
Very Unpreventable	2 (3)	3 (4)	0
Quite Unpreventable	4 (5)	14 (18)	9 (12)
Neither unpreventable or preventable	9 (12)	20 (26)	28 (37)
Quite Preventable	51 (67)	36 (47)	38 (50)
Very Preventable	10 (13)	3 (4)	1 (1)
Total n	76	76	76

6.3.4   Intention to use the exercise programme

Fifty-six coaches (74%) reported being "very likely" to use the programme following the "coach the coaches" workshops, whilst 17 coaches (22%) reported being "quite likely", 2 coaches (3%) reported being "quite unlikely", and 1 coach (1%) reported being "very unlikely" to use their allocated programme.

Table 6.4   Baseline perceived task self-efficacy. Data presented as raw frequencies (%)

How confident are you…	
…that you understand the programme well enough to use it with your players?	
Very Unconfident	1 (1)
Quite Unconfident	0
Neither Unconfident or Confident	1 (1)
Quite Confident	27 (36)
Very Confident	47 (62)
Total n	76
…that you have the ability to lead the programme with your players?	
Very Unconfident	1 (1)
Quite Unconfident	1 (1)
Neither Unconfident or Confident	3 (4)
Quite Confident	21 (28)
Very Confident	50 (66)
Total n	76

Associations between HAPA predictor variables and coach intention to use the programme are presented in table 6.5. The only statistically significant association was noted between task self-efficacy and intent to use the programme (ρ=0.38, 90% CL 0.16-0.58, *P*=0.004).

Table 6.5   Correlation matrix (Spearman's ρ) for psychosocial variables with 90% confidence limits (n=76)

	Risk Awareness	**Outcome Expectancy**	**Task Self-Efficacy**
Outcome Expectancy	0.19 -0.04 to 0.40	--	
Task Self-Efficacy	-0.07 -0.33 to 0.17	0.03 -0.23 to 0.27	--
Intention	0.01 -0.23 to 0.25	0.17 -0.04 to 0.37	**0.38*** **0.16 to 0.58**

* Statistically significant association (Bonferroni-adjusted *P*=0.004)

6.3.5   *Coping Self-Efficacy, Recovery Self-Efficacy, and Action Planning*

Perceived coping and recovery self-efficacy values are presented in table 6.6. Internal consistency for coping self-efficacy was α=0.80. Seventy-nine percent (79%) of coaches felt "quite" or "very" confident in continuing to use the programme in the event that their players did not enjoy completing the programme, whilst 57% also felt "quite" or "very" confident in using the programme even if completion took too long, but only 44% felt "quite" or "very" confident in using the programme if it did not contain enough sport-specific content. Ninety-four percent (94%) of coaches also felt "quite" or "very" confident in continuing to use the programme, even if they had missed completing the programme at a session or match.

Table 6.6   Baseline perceived coping and recovery self-efficacy. Data

presented as raw frequencies (%)

How confident are you about continuing to use the programme, if…	
…your players do not enjoy performing the programme? (CSE)	
Very Unconfident	2 (3)
Quite Unconfident	8 (10)
Neither Unconfident or Confident	6 (8)
Quite Confident	26 (34)
Very Confident	34 (45)
Total n	76
…the programme took too long to complete? (CSE)	
Very Unconfident	4 (5)
Quite Unconfident	16 (21)
Neither Unconfident or Confident	13 (17)
Quite Confident	22 (29)
Very Confident	21 (28)
Total n	76
…the programme did not contain enough rugby-specific content? (CSE)	
Very Unconfident	8 (10)
Quite Unconfident	24 (32)
Neither Unconfident or Confident	11 (14)
Quite Confident	18 (24)
Very Confident	15 (20)
Total n	76
...you did not complete the programme at one session? (RSE)	
Very Unconfident	1 (1)
Quite Unconfident	1 (1)
Neither Unconfident or Confident	3 (4)
Quite Confident	24 (32)
Very Confident	47 (62)
Total n	76

CSE – Coping self-efficacy. RSE – Recovery self-efficacy.

Coach perceptions relating to action planning are outlined in table 6.7. Internal

consistency for action planning was $\alpha=0.89$. Ninety-eight percent (98%) of coaches

felt "quite" or "very" sure about teaching their players to perform the exercises,

whilst 98% also felt "quite" or "very" sure about when to complete the programme

during a session. In addition, 92% of coaches felt "quite" or "very" sure about

overcoming any challenges that they were faced with to use the programme, and 95% felt "quite" or "very" sure about encouraging their players to perform the exercises to the best of their ability.

Table 6.7   Baseline action planning. Data presented as raw frequencies (%)

How sure are you about…	
…teaching your players to perform the exercises?	
Very Unsure	1 (1)
Quite Unsure	1 (1)
Neither Unsure or Sure	1 (1)
Quite Sure	24 (32)
Very Sure	49 (65)
Total n	76
…when, during a session, to complete the programme?	
Very Unsure	1 (1)
Quite Unsure	1 (1)
Neither Unsure or Sure	0
Quite Sure	18 (24)
Very Sure	56 (74)
Total n	76
…overcoming challenges to maintain your intention to use the programme?	
Very Unsure	0
Quite Unsure	2 (3)
Neither Unsure or Sure	4 (5)
Quite Sure	37 (49)
Very Sure	33 (43)
Total n	76
...encouraging your players to perform the exercises to the best of their ability?	
Very Unsure	1 (1)
Quite Unsure	0
Neither Unsure or Sure	3 (4)
Quite Sure	28 (37)
Very Sure	44 (58)
Total n	76

6.3.6   Association between psychosocial factors and programme compliance

The association between psychosocial factors and coach compliance with using the preventive exercise programmes is illustrated in figure 6.2. Coaches with stronger intentions to use the programme were 49% more likely to be categorised into the high compliance group than coaches with weaker intentions (PR=1.49, 90% CL 1.11-2.00, *likely higher effect*). Conversely, coaches who were more risk-aware (i.e. perceived risk and severity of rugby-related injuries) were 33% less likely to be categorised into the high compliance group than coaches who were less risk-aware (PR=0.67, 90% CL 0.45-0.99, *likely lower effect*). In addition, coaches with more favourable outcome expectancies were 23% less likely to be categorised into the high compliance group than coaches with less favourable outcome expectancies (PR=0.77, 90% CL 0.53-1.11, *likely lower effect*). Coaches with clearer action plans relating to programme use (i.e. ability to plan how, when, and where they would use their programme) were 33% more likely to be classified into the high compliance group than coaches with less discernible action plans (PR= 1.33, 90% CL 0.93-1.89, *likely higher effect*).
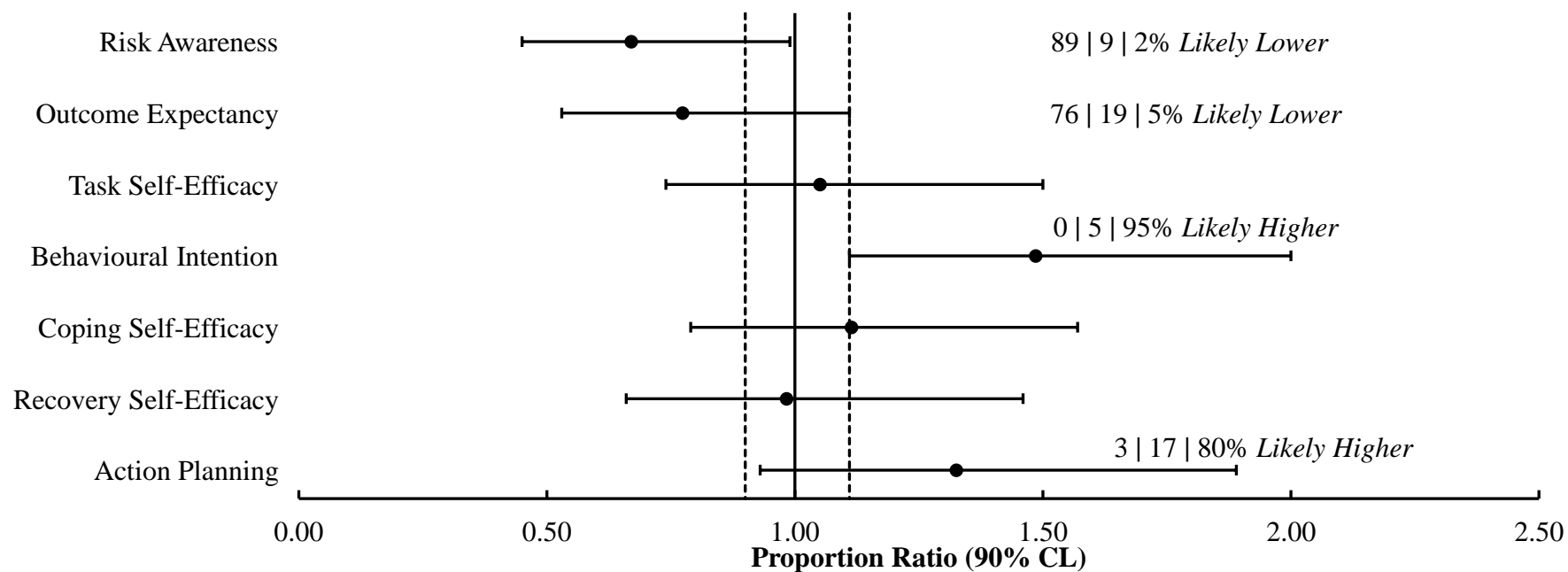
Figure 6.2   Forest plot illustrating the association between psychosocial factors and the likelihood of coaches maintaining high compliance with using a preventive exercise programme. Data presented as the ratio between the proportion of coaches demonstrating high levels of each psychosocial variable that were categorised as maintaining high compliance, relative to the proportion of coaches demonstrating low levels of each psychosocial factor that were categorised as maintaining high compliance. Dotted vertical lines represent the thresholds for smallest worthwhile effects (PR= 0.90 and 1.11. Data labels reflect the % likelihood that each effect is lower | trivial | higher than smallest worthwhile effects for psychosocial variables that demonstrate a clear association with compliance

6.4   Discussion

This study aimed to investigate psychosocial factors and their association with compliance with using a preventive exercise programme amongst youth rugby coaches. Principal findings indicated that coaches with stronger intentions and clearer action plans relating to using their allocated programme were 33-49% more likely to maintain high compliance with programme use than their counterparts. Conversely, coaches with greater risk awareness and more favourable outcome expectancies of programme use were 23-33% less likely to maintain high programme compliance.

In contrast to previous research, most coaches in this study reported feeling "quite" or "very" confident in their understanding of the programme (98%), and in their ability to lead the programme (94%). McKay et al. (2016) identified comparatively lower levels of task self-efficacy amongst a cohort of soccer coaches, citing the lack of familiarity with the FIFA "11+" exercise programme as a potential contributing factor in this finding. There are several primary sources by which self-efficacy can be enhanced: experience of performance accomplishment, indirect (vicarious) experience of the accomplishment of others, verbal persuasion, and internal physiological states (Bandura, 1977). Of the 54 coaches to complete this study, 19 (35%) reported at baseline that they had previously used physical conditioning programmes to enhance performance with their players, of which all referred to strength and conditioning practices when asked to elaborate. It is possible that coaches in this study with previous experience of using physical conditioning programmes may already have a degree of mastery experience that subsequently led to higher perceived understanding and self-efficacy in leading a preventive exercise programme with their players. In contrast, other coaches with little or no prior experience of using physical conditioning programmes with their players may have been more reliant on knowledge of other similar teams finding success in using preventive exercise programmes, or receiving verbal assurances from the research team during the "coach the coaches" workshops. Task self-efficacy has been assumed to become more influential than outcome expectancies in forming a behavioural intention once a sufficient level of experience of the target behaviour has

been achieved (Schwarzer, 2014). Until this threshold is reached, outcome expectancies may be considered to influence intention more strongly than self-efficacy. On this basis, implications for developing strategies to improve intention forming could consider the influence of experience of coaches in identifying whether to focus on improving outcome expectancies or task self-efficacy.

A statistically significant association between task self-efficacy and intention to use the programme was identified in this study (ρ=0.38, P=0.004), in line with a similar study amongst youth soccer coaches that also identified an association between task self-efficacy and intention to use a preventive exercise programme (ρ=0.42) (Owoeye et al., 2017a). Task self-efficacy has been shown to play an important role in facilitating health behaviour change across a number of settings (De Nooijer, De Wit, & Steenhuis, 2004; Lippke et al., 2004b; Newton et al., 2014; Schwarzer et al., 2007), and in particular in forming intentions during the pre-intentional stage of the HAPA model (McKay et al., 2016; Owoeye et al., 2017a; Schwarzer, 1992; Schwarzer & Renner, 2000; Schwarzer et al., 2003). In line with existing literature around the HAPA model (Lippke et al., 2005; Schwarzer, 1992; Schwarzer & Renner, 2000), this study's findings may indicate that task self-efficacy is of relatively high importance to forming an intention to use a preventive exercise programme amongst youth rugby coaches. Furthermore, self-efficacy has been shown to be a modifiable factor that may benefit from introducing targeted interventions amongst coaches, such as the provision of comprehensive workshops that include practical demonstrations of the exercise programme (Owoeye et al., 2017b; Steffen et al., 2013b), as well as peer-related role modelling and mentorship opportunities (McKay et al., 2016; White, Donaldson, & Finch, 2015). Developing and evaluating whether such interventions can enhance self-efficacy amongst primary programme adopters bears the need for further research.

Coaches that demonstrated stronger intentions to use their exercise programme were 49% more likely to maintain high programme compliance during the study than their counterparts with weaker intentions (PR=1.49, 90% CL 1.11-2.00, *likely higher effect*). This finding is in line with a number of previous applications of the HAPA model to predict changes in exercise and physical activity behaviour across varying

populations (Clark & Bassett, 2014; Lippke, Ziegelmann, & Schwarzer, 2004a; Lippke et al., 2004b; Schwarzer et al., 2007), but is in contrast to the findings of Frank, Register-Mihalik, and Padua (2015), who determined that an increase in intent to use a knee ligament injury prevention programme following a workshop did not translate to sufficient uptake amongst youth sport coaches. This discrepancy could be due to the different measures of adoption used in the present versus the previous study, the latter of which was based on a single session observation during the playing season. In contrast, the present study monitored compliance with programme use through the entire playing season amongst youth rugby coaches and so may be more representative of programme adoption.

While intention has been regarded as the best predictor of subsequent behaviour (Schwarzer & Renner, 2000), not all intentions are translated into behaviour due to the so-called "intention-behaviour" gap (Sniehotta et al., 2005a). Coping self-efficacy, recovery self-efficacy, and action planning are recognised as essential proximal factors to translating intentions to new behaviours. A lack of self-efficacy or appropriate planning may predispose to falling back into old habits or abandoning a new behaviour due to unforeseen barriers (Schwarzer et al., 2007). In this study, coaches with clearer action plans of how to initiate programme use with their players were 33% more likely to maintain high programme compliance when compared with their peers (PR= 1.33, 90% CL 0.93-1.89, *likely higher effect*). Action planning should detail how and under what situations an intended behaviour ought to be implemented (Armitage & Conner, 2000), and in doing so should make situational cues more accessible and lead to faster enactment of a target behaviour (Sniehotta, Schwarzer, Scholz, & Schüz, 2005b). Results here could indicate that coaches with clearer action plans could continue with using the exercise programme, as opposed to falling back into using previous warm-up routines with their players or giving up using the programme upon encountering barriers. For example, coaches with clearer action plans about using the delivery support materials (laminated cue cards, programme manual, films of individual exercises) may have been more comfortable in teaching the programme to their players and progressing to new phases. Several studies have also identified associations between self-efficacy, intention, and action planning in predicting behaviour change (Clark & Bassett, 2014; Lippke et al.,

2004a; Luszczynska & Schwarzer, 2003; Sniehotta et al., 2005a), highlighting that individuals with high self-efficacy and stronger intentions may be able to generate a greater number and quality of action plans that are needed to initiate and maintain new behaviours, which may in turn aid in maintaining behaviour and recovering from setbacks (Schwarzer et al., 2003). This is supported by a study conducted in orthopaedic outpatients who were receiving exercise therapy, which identified that patients that intended to adhere to exercise guidelines benefitted from a planning intervention, whilst counterparts with no intention received no benefit from the same planning intervention (Lippke et al., 2004b). Studies have yet to investigate the effect of strategies to promote action planning on behaviour change among sporting populations, but potential situational cues that could aid injury prevention action planning among coaches include placing exercise cue cards in visible places, preparing the layout for the exercise programme before players arrive, and not introducing additional equipment such as rugby balls into the session until after the programme has been completed (Verhagen et al., 2010).

Coaches with greater baseline risk awareness were 33% less likely to maintain high programme compliance than their counterparts (PR=0.67, 90% CL 0.45-0.99, *likely lower effect*). This finding is supported by the trivial associations between risk awareness and intention noted in this study (ρ=0.01), which is consistent with applications of the HAPA model in other settings that have identified risk awareness as a weak predictor of forming an intention to change a behaviour (McKay et al., 2016; Schwarzer, 2008; Schwarzer & Renner, 2000). It has been suggested that risk awareness may only be an important factor for intention formation in individuals with no prior intention of adopting a new behaviour (Lippke et al., 2004a). It is possible that coaches in this study had already contemplated injury risk and possible outcomes associated with warm-up programmes, or had already formed an intention to use the programme prior to the "coach the coaches" workshops, given that their participation in this study was partly the result of self-selection. Thus, coaches may have already been close to forming an intention or had indeed formed an intention to adopt the preventive exercise programme, hence the lack of positive association between risk awareness with intention and compliance with using the programme. Communication of risk information remains a widely-used strategy in seeking to

alter behaviour, despite limited success (Ruiter, Kessels, Peters, & Kok, 2014). While evidence from the sports injury prevention literature remains scarce, one study found that trying to raise awareness of injury risk alone in soccer players was not successful in reducing injury risk (Arnason, Engebretsen, & Bahr, 2005). Although risk awareness alone is regarded as insufficient to enable an individual to form an intention, it may act together with outcome expectancies and self-efficacy to promote forming an intention, as coaches may not contemplate the outcomes of changing behaviour unless there is sufficient level of risk attached to their existing habits (Schwarzer et al., 2003). As such, improving risk awareness may still be an important step, but this should be in concert with developing outcome expectancies and self-efficacy in producing an intention to act.

There were several limitations of this research that must be acknowledged. The conclusions from this study have been drawn from analysis of a combined dataset containing coaches that received either the intervention or standardised control programmes. Initial analyses were conducted separately for the intervention and control groups. No clear effects of psychosocial factors on programme compliance were noted within either of the groups, following which the respective datasets were collapsed for further analyses. However, it is possible that coaches differed in how they regarded the exercise programme that they received, and that different antecedent psychosocial factors may have contributed in differing magnitudes to intention forming and programme compliance between the two cohorts. For example, the control exercise programme contained exercises that many coaches may have been familiar with, whilst the intervention contained novel exercises that many coaches might not have used before. Given that one potential source of self-efficacy is previous experience of accomplishment (Bandura, 1977), it is plausible that self-efficacy may have had a greater influence on intention forming and programme compliance with the control programme than the intervention programme. Although the questionnaire that was used in this study was adapted from a questionnaire that was previously used and found to perform well in another youth sport setting (McKay et al., 2016; McKay et al., 2014b), this specific questionnaire has not yet been validated and findings should be interpreted with caution. It was beyond the scope of this study to focus on player-related psychosocial factors, and

the current findings from coaches may have limited applications for players (McKay et al., 2014a; McKay et al., 2016). This study considered the association between intrinsic psychosocial factors and coach compliance with using the programmes, but gave little consideration towards the presence of external barriers or programme modifications that may indicate how to overcome logistical or environmental challenges experienced by coaches (O'Brien, Young, & Finch, 2016; Twomey, Doyle, Lloyd, Elliot, & Finch, 2015). Although the recruitment of schools into this sub-study was randomised (*see Chapter 5*), all schools that were involved in the wider RCT had returned an interest in participating. It is possible that this introduced a self-selection bias amongst coaches involved in this trial, in that some coaches may have already formed an intention to use the preventive exercise programme prior to the "coach the coaches" workshops. It was not possible to identify whether this was the case for all coaches but may it limit the generalisability of this study's findings to populations of coaches that have yet to form intentions to use a preventive exercise programme.

The HAPA model's structure infers that individuals should fall into different stages depending upon whether or not they have formed intentions to adopt a new behaviour, or whether they have adopted and now need to maintain a new behaviour. It has been shown that different groups within the HAPA model may react in different ways to targeted interventions designed to enhance certain psychosocial factors. For instance, promising results have indicated that focusing on planning and self-efficacy may enhance the translation of an intention to a behaviour amongst groups who have already formed an intention (Lippke et al., 2004a, 2004b). In the context of this study's findings, future research may wish to identify where coaches are categorised within the HAPA model framework before developing and evaluating the effect of targeted interventions (particularly for task self-efficacy, intention, and action planning) in translating intentions to behaviour. Several examples of interventions for coaches could include: facilitating practical demonstrations of the programme, mentorship or peer-related role-modelling opportunities, and identifying appropriate situational cues to aid programme use.

6.5   Conclusion

This study represents one of the first attempts in sports injury prevention research to investigate the association between psychosocial factors on compliance with using a preventive exercise programme amongst coaches. Its main findings are that coaches that exhibited stronger intentions and clearer action plans relating to preventive exercise programme use were more likely to maintain high compliance with programme use compared with their peers. Conversely, coaches that exhibited higher levels of risk awareness were less likely to maintain high compliance with programme use. These findings provide a basis from which to inform delivery strategies to enhance compliance with using preventive exercise programmes, which should focus on developing coaches' task self-efficacy, intentions and action planning.

CHAPTER SEVEN

General Discussion

7.1   Introduction

This thesis aimed to investigate injury risk factors and preventive strategies in schoolboy Rugby players. Several novel research questions were posed in Chapter One of this thesis, which were subsequently addressed in Chapters Three to Six. The purpose of this present Chapter is to provide a synthesised summary of the principal research findings and to critically assess the extent to which the research questions have been addressed. Through this approach, the original and significant contribution to current knowledge made by these findings will be outlined. Moreover, the potential practical implications of this body of work, as well as recommendations for future research are offered.

7.2   Addressing the Research Questions

There had been few documented attempts to identify potentially modifiable risk factors in schoolboy Rugby players, whilst accounting for the confounding effect of other variables. Knowledge of which risk factors might influence injury risk, whilst also being changeable, is important in advising the formulation of targeted preventive interventions. There is reason to suggest that intrinsic factors such as anthropometry and components of physical fitness may influence injury risk in young athletes. As such, these considerations led to the development of the first research question:

i. Are selected anthropometric, and physical fitness characteristics associated with injury incidence in youth rugby players?

Key findings:

Adjusting for several other prospective risk factors, taller youth rugby players remained at an increased risk of injury.

Players that reported experiencing pain on several Functional Movement Screen sub-tests were at an increased risk of injury.

Demonstrating no left-right movement asymmetries during the Functional Movement Screen was associated with a protective effect on injury risk.

Preventive exercise programmes have been shown to reduce injury risk in other team sport environments, but to-date there had been no attempts to determine the efficacy of a targeted movement control exercise programme in reducing injury risk across schoolboy Rugby players. Furthermore, programme compliance (completion relative to potential maximum) and dose (frequency of completion) have been shown to be important factors that need to be accounted for when evaluating the efficacy of preventive programmes. For these reasons, it was important to address the following research questions:

ii. **Can a pre-activity movement control training programme reduce injury outcome measures during 12 weeks of use, when compared with a standardised control exercise programme in youth rugby players?**

Key findings:

Intention-to-treat analyses revealed *unclear* effects of exercise programme allocation on overall match injury incidence (Incidence RR= 0.85, 90% CL 0.61-1.17).

Clear beneficial effects for concussion risk (Incidence RR= 0.71, 90% CL 0.48-1.05) and upper limb injury burden (Burden RR= 0.66, 90% CL 0.40-1.10) were noted in the intervention group following intention-to-treat analysis.

iii. **Is the weekly dose (frequency of completion) of a movement control training programme associated with injury outcome measures during 12 weeks of use in youth rugby players?**

Key findings:

Per-protocol analysis of teams that complet**ed** the intervention or control programme three or more times per week **on average** revealed that the intervention group

suffered 72% fewer overall match injuries (Incidence RR= 0.28, 90% CL 0.14-0.51) than the control group.

The intervention group also suffered 72% fewer match contact injuries than the control group (Incidence RR= 0.28, 90% CL 0.14-0.56).

Intervention teams that completed the preventive exercise programme three or more times per week on average suffered 39% fewer overall match injuries than intervention teams that averaged completing the programme at fewer than three sessions per week (Incidence RR= 0.61, 90% CL 0.42-0.88).

iv. Is compliance with using a movement control training programme (proportion of all possible programme parts completed) associated with injury outcome measures during 12 weeks of use in youth rugby players?

Key findings:

Intervention teams who were ranked as having high compliance with using the preventive exercise programme suffered 43% fewer overall match injuries than intermediate compliance teams (Incidence RR= 0.57, 90% CL 0.38-0.85).

High compliance intervention teams also suffered 44% fewer match contact injuries than intermediate compliance teams (Incidence RR= 0.56, 90% CL 0.37-0.85).

The influence of high programme compliance and dose in reducing injury risk in schoolboy Rugby players highlights the need to formulate strategies that can maximise programme uptake amongst programme delivery agents, such as coaches. Few studies had investigated the association between psychosocial factors and the adoption of new safety behaviours, which may provide useful information of which psychosocial factors need to be targeted to maximise programme compliance.

v. Are coach-related psychosocial factors related to compliance with using a movement control or standardised control exercise programme in youth rugby?

Key findings:

Task self-efficacy was the only psychosocial factor to be significantly related to intention to use the programme amongst coaches.

Coaches with stronger intention to use the programme with their players were 49% more likely to be categorised as having high programme compliance than coaches with weaker intentions at the end of the season.

Conversely, coaches that were more risk aware or had more favourable expectations about using the programme were 23-33% less likely to be categorised as having high programme compliance than their counterparts.

Coaches with clearer action plans relating to programme use were 33% more likely to be classified as having high programme compliance than coaches with less distinct action plans.

7.3   Original Contribution to Knowledge

There are several means by which to make an original contribution to knowledge. As posited by Phillips and Pugh (2007) in the case of doctoral research, these may include:

- Setting down a major piece of new information in writing for the first time
- Continuing a previously original piece of work
- Carrying out original work designed by the supervisor
- Providing a single original technique, observation, or result in an otherwise unoriginal but competent piece of research
- Having many original ideas, methods, and interpretations all performed by others under the direction of the postgraduate
- Showing originality in testing somebody else's idea

To this end, this thesis makes an original and meaningful contribution to knowledge through:

- Identifying relationships between as-yet to be investigated risk factors (movement competency, movement asymmetry) and injury risk in schoolboy rugby players.

- Detailing the process of formulating an evidence and theory-based preventive exercise programme that combines scientific evidence, expert knowledge, and end user perspectives.

- Providing the first cluster randomised controlled trial in schoolboy Rugby to evaluate the efficacy of a pre-activity movement control exercise programme in reducing injury risk.

- Reinforcing the importance of accounting for programme compliance and dose when evaluating the efficacy of preventive exercise programmes.

Using an established behaviour change model to evidence the associations between coach-related psychosocial factors and compliance with preventive exercise programme use as a behavioural outcome.

7.4 Practical Implications and Potential Impact

The principal aim of this body of work was to produce research that could further collective understanding of the factors that contribute to injury in schoolboy rugby players and to evaluate if a prospective bespoke intervention could reduce injury risk in this population, thereby informing practice amongst key stakeholders. As such, it is important to consider the practical implications arising from the findings of this thesis, and particularly how these might be translated into informing practice. The target stakeholder groups that are likely to be impacted by this work include governing body policy makers, administrators, coaches, clinicians, and parents.

Firstly, the association between baseline reports of pain on certain FMS sub-tests and subsequent injury risk presents some interesting implications. Movement screening is a common practice in the physical preparation of athletes, and in particular the FMS is one of the commonly used tools to assess movement quality (McCall et al.,

2015). Much of the interest in movement screening has focused on the association between movement limitation and injury risk, and not so much the relationship between experiencing pain during movement screening with injury risk. The findings of Chapter Three suggest that identifying if pain is experienced during movement screening may be equally, if not more, important than identifying movement limitations in youth sport settings. This implication could apply to pre-participation screening to ensure readiness to participate, or to return-to-play screening to ensure that athletes are not returning to sports participation whilst suffering from the residual effects of injury.

Secondly, this thesis provided an evidence and theory-informed framework from which to formulate a preventive exercise programme for youth team sports. Accounts of developing preventive exercise programmes have been scarce until recently, and there has been little in the way of consensus relating to which processes should be incorporated into such a framework. Given that existing preventive exercise programmes may not be readily applicable to different sports, playing levels, or athlete needs, there will be a need to continue to develop new preventive exercise programmes. The generation of a consensus regarding the formulation of preventive exercise programmes in sport could be useful in ensuring that subsequently formulated programmes are evidence-informed and context-appropriate, which may subsequently aid in achieving stakeholder buy-in.

Perhaps the most profound findings from this body of work come from Chapter Five, which aimed to evaluate the efficacy of a pre-activity movement control exercise programme in reducing injury risk in schoolboy rugby players. The potential impact of these findings is due to: the heightened public scrutiny surrounding the nature and impact of injuries sustained by schoolboy rugby players at present, particularly concussion; and demonstrating that preventive exercise programmes can injury risk (notably concussion) in contact sports where before their efficacy was uncertain. Determining efficacy under controlled settings is needed for implementation of preventive interventions in everyday settings (Finch, 2006), and so the findings of this research represent an essential step towards impacting injury risk in schoolboy rugby through implementing the preventive exercise programme in wider

populations. The results of Chapter Five have recently become the evidence base from which the Rugby Football Union (governing body for rugby in England) will attempt to disseminate and implement the tested exercise programme nationally across the youth community Rugby population, thereby demonstrating the potential for the results of this work to meaningfully impact on policy in youth Rugby.

The findings of Chapters Five and Six will be very useful in informing the delivery strategy that will be required to disseminate the preventive exercise programme to target audiences. Understanding that completing the programme at least three times per week can lead to the greatest reductions in injury risk will be an important message to convey to prospective delivery agents, as well as establishing a threshold for minimum effective programme dose in this context. Moreover, strengthening behavioural intentions to use the programme (through improving task self-efficacy) and enhancing the quality of action plans may serve to optimise compliance with programme use amongst delivery agents. In addition, the findings of Chapter Six will be a useful starting point in identifying areas for future research on behaviour change in sports injury prevention (discussed below).

7.5   Future Directions

Most of the research questions that were posed in this thesis have not been addressed previously in schoolboy Rugby players. This section aims to outline the potential for future research that may seek to build upon the findings from the present programme of work.

Firstly, further research is required to substantiate the findings of Chapter Three, principally regarding the association between anthropometric profile and injury risk in schoolboy rugby players. This research may be particularly important, given the recent calls in some quarters for investigations into whether grouping young rugby players by physical maturity or anthropometric profile as opposed to chronological age (*bio-banding*) can be used to reduce injury risk (Archbold et al., 2015; Tucker et al., 2016). In theory, bio-banding is thought to protect the less physically developed individuals within each banding. However, the findings from Chapter Three run in contravention to this, as taller players were at a meaningfully increased injury risk. In addition, a recent study conducted in a similar population of schoolboy Rugby players identified that heavier schoolboy Rugby players (>77 kg) were 32% more likely to sustain a time-loss match injury than lighter counterparts (≤77 kg) (Archbold et al., 2015). Research into other potential mediators between anthropometric profile and injury risk in youth rugby should be considered. For instance, it is possible that anthropometric profile might influence technical skill level in young athletes, with the result that the interaction between these two characteristics might influence injury risk. Both anthropometry and technical skill level have been shown to influence injury risk in adolescent rugby players (Archbold et al., 2015; Burger et al., 2016; Hendricks et al., 2015a), however, there have been no studies to-date that have accounted for the mutual effects of these prospective risk factors on injury risk. The findings of this further research may be important in judging whether bio-banding is a viable option for reducing injury risk in youth rugby amongst other contact sports.

Moreover, future research to build on the findings of Chapter Three should seek to identify risk factors for priority injury types in youth rugby players. It is through identifying modifiable factors for the occurrence of priority injury types that targeted

interventions may be developed that would have the greatest impact in reducing the overall risk and burden of injury in youth rugby. For instance, concussion and joint-related injuries are currently regarded as high risk injury types in youth rugby players (Archbold et al., 2015), and would benefit from specific attention to address risk factors and prospective measures for their prevention (Hendricks et al., 2015a; Hendricks et al., 2016)

The primary aims of Chapter Five were to evaluate the efficacy of a preventive exercise programme in schoolboy rugby players, and to determine the influence of programme dose and compliance on injury outcome measures. It was beyond the scope of the study to identify any physical performance changes that may have occurred from programme use amongst players. This additional information may have been useful in identifying the potential mechanisms by which the programme reduced injury risk in players. As present, it can only be speculated that reductions in concussion risk were due to increased neck strength and/or preserved neck function amongst players that used the intervention programme. Similarly, the reduction in upper limb injury burden may be speculated to have been through improved in upper limb force-handling capabilities and kinematics. Therefore, future research may wish to study the potential physical performance effects of the preventive exercise programme that was evaluated in Chapter Five of this thesis. Another possible positive outcome of this proposed research direction may be that any documented improvements in physiological fitness could be useful in promoting programme use to coaches.

Another key implication from Chapter Five relates to the important influence of programme compliance on programme efficacy. Compliance was treated as an overall index in Chapter Five, with no emphasis given to compliance with using specific parts of the programme on injury risk changes. Recent meta-analytical studies have pointed to the need for programmes to include both proprioceptive and resistance training exercise in the regimen to optimise injury risk reductions (Lauersen et al., 2014). Further research into the effect of compliance with using specific parts of the preventive exercise programme on injury risk outcomes may be a useful avenue to follow. From a practical perspective, this information may be

useful in advising coaches on which programme parts to prioritise when faced with constraints such as lack of time or inappropriate facilities.

Little is known about the time-course of compliance with preventive exercise programmes, nor about the time-frame in which effects on injury risk may occur. It has been suggested that the physiological effects thought to underpin the efficacy of preventive exercise programmes could be an acute and cumulative response to programme use (Impellizzeri et al., 2013; Root, Trojian, & Martinez, 2015). Moreover, it has been shown that programme compliance deteriorates over prolonged periods of use (Hägglund et al., 2013). How the longitudinal effects of programme compliance impact injury risk could be of considerable importance if strategies to maintain or improve compliance levels amongst programme delivery agents are required. Additionally, evidence of whether physiological effects occur acutely or cumulatively with preventive exercise programme use could be valuable if disseminated to prospective delivery agents.

The results of several studies have indicated that it is preferable to deliver preventive exercise programmes to key target stakeholders through comprehensive face-to-face workshops, as this strategy has been shown to optimise programme compliance rates and improve the task self-efficacy of delivery agents (Steffen et al., 2013b). Based on the findings of Chapter Six, it would also be preferable to determine the utility of other strategies that could improve task self-efficacy and behavioural intention, such as peer-related role modelling or having access to mentors (White et al., 2015), as well as action planning related to programme use. Providing delivery agents with situational cues that could aid programme use, such as laminated cards that can be referred to whilst leading the programme, is one such example of a strategy that could be researched in future. Given that delivery agents may react differently to the same delivery strategy depending on whether they intend to use the programme, there is also be a need to investigate how to tailor delivery strategies to prospective delivery agents in order to develop an intention to use the programme or to translate the intention into a new behaviour, in this case using the programme.

7.6   Thesis Conclusions

This thesis aimed to identify risk factors for injury and preventive strategies in schoolboy Rugby Union. In doing so, five novel research questions were addressed in this body of research.

During the course of this thesis, several modifiable injury risk factors were identified in adolescent schoolboy Rugby players, raising the implication that movement screening practices in this population should seek to identify and correct pain and movement asymmetry in players as part of pre-participation and return-to-play protocols. Taller rugby players were also identified as an at-risk population, thereby highlighting the need for further research to identify the underlying mediating factors for this association with increased injury risk. Moreover, a newly-formulated movement control exercise programme was shown to reduce upper limb injury burden and concussion risk in schoolboy Rugby players compared with a standardised control programme, although teams that completed the programme three or more times per week during the study achieved more extensive reductions in injury risk. Ensuing study of the relationships between delivery agent psychosocial factors and programme compliance revealed associations between programme compliance with behavioural intention and action planning, thereby highlighting the importance of enhancing these factors amongst prospective programme delivery agents in future implementation strategies.

In conclusion, the findings from this thesis contribute to furthering the understanding of injury risk factors and prevention in schoolboy Rugby, and in doing so provide important and impactful implications for injury prevention practice and research in this population.

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Appendices

APPENDIX A: PARTICIPANT (PLAYER) INFORMATION AND CONSENT FORM (CHAPTER THREE)

RFU Youth Rugby Study (FMC: RUGBY) 2015/16
Player Information Sheet & Consent form

Using Functional Movement Control Principles to Reduce Injury and Enhance Performance in Youth Rugby Players

Principal Investigator: Dr Grant Trewartha
Other investigators: Dr Keith Stokes, Mr Michael Hislop, Dr Sean Williams

We are asking you to take part in a study of training, performance and 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 your rugby programme team (coach/doctor/nurse/physiotherapist) or contact us 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 Player Consent Form.

Background to the study
Rugby players need to show strength, speed, power and endurance. All of these aspects of fitness are linked to something called functional movement control (FMC). FMC includes elements of strength, flexibility, motion, stability, resistance to fatigue and body position sense.
Studies in some sports have shown that low FMC scores are linked to injury. This has not yet been shown in rugby. We think that simple exercise programmes that improve FMC can reduce the risk of injury in rugby players.
It is also possible that improving functional movement control will improve physical performance.

What does the study involve?
We will visit your school/club at the beginning and at the end of the season. On these visits, we will ask you to perform functional movement screening and physical fitness tests. During the season:
☐ your coach will record the amount of time you spend rugby training and playing in rugby matches
☐ details of any injury you get in rugby matches or training which cause you to miss a day's training will be recorded by your school doctor/nurse/physiotherapist

This information will be analysed by researchers at the University of Bath.

Whom are we asking to take part?
All players in U15-U18 squads in a sample of English schools and clubs.

Do I have to take part?
It is up to you whether you take part in the study. You do not have to take part but the more players who take part, the more we will find out about youth rugby. If you want to take part, you must sign a consent form that confirms you have read this information and you agree to be included in the study. You can withdraw from the study by contacting us at any time without giving a reason.

What do I have to do?
We will visit your school/club at the beginning and end of the season, and we will ask you to perform some simple functional movement (flexibility, balance) and physical fitness (strength, speed, agility) tests. During the season, we will ask you complete a simple daily record of your training, sleep quality and general wellness.

Are there any risks from taking part?
The functional movement tests are not tiring. The fitness tests will require a lot of effort but you will be used to this type of exercise in your rugby training. If you have any injuries that limit your movement, we will not ask you to do certain tests.

Will information about me be kept confidential?
The Data Protection Act says that we must have your permission to collect information about your test results during the course of this study. All information collected is stored using a code number rather than your name. Your results will be reported back to coaching staff at your school/club.

What will happen to the information from the study?
The information will be analysed by researchers at the University of Bath. We will produce a report about how functional movement and physical fitness are linked with injury in youth rugby. No personal references will be made in any report.

For further information, or if you have any questions, contact Dr Grant Trewartha, University of Bath. (Tel: 01225 383055; e-mail:rfu-youth@bath.ac.uk)

RFU Youth Rugby Study (FMC: RUGBY) 2015/16
Player Information Sheet & Consent form

Player consent form

I have read and understand the information about this study and I have had a chance to ask questions.

I agree to take part in the study and give consent for researchers to carry out functional movement screening and fitness tests on me. I agree that the information will only be used for research purposes and in a report to my school/club. Information in which I can be identified will only be made in feedback to me and to coaching staff at my school/club.

I understand that I can withdraw from this study at any time without being asked why.

Participant:

_____   _____   _____
Name   Date   Signature

For participants aged under 18 years on the first day of the playing season:

Coach (in loco parentis):

_____   _____   _____
Name   Date   Signature

For participants who turn 18 years during the study period to re-consent to participation:

_____   _____   _____
Name   Date   Signature

Researcher taking consent:

_____   _____   _____
Name   Date   Signature

In the event that you longer wish to participate in the study at a later date, please tick one of the boxes below:

I am happy for any prior data collected from me to be used by the   ☐
researchers

I am not happy for any prior data collected from me to be used by the researchers   ☐

OFFICE USE ONLY

SCHOOL   [   ]

PLAYER PROJECT ID   [   ]

PLAYER SEASON ID   [   ]

For further information, or if you have any questions, contact Dr Grant Trewartha, University of Bath. (Tel: 01225 383055; e-mail:rfu-youth@bath.ac.uk)

APPENDIX B: PARTICIPANT (PLAYER) INFORMATION AND CONSENT FORM (CHAPTER FIVE)

RFU Youth Rugby Study (FMC: RUGBY) 2015/16
Player Information Sheet & Consent form

The efficacy of a movement control training protocol to reduce injuries in youth rugby

Principal Investigator: Dr Grant Trewartha
Other investigators: Dr Keith Stokes, Mr Michael Hislop, Dr Sean Williams, Dr Carly McKay

We are asking you to take part in a study of physical preparation and injury occurrence in young rugby players, 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 your rugby programme team (coach/doctor/nurse/physiotherapist) or contact us 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 Player Consent Form.

Background to the study
Injuries are an unfortunate part of sport for youth athletes, and rugby is no different. However, there are some injuries that may be preventable through improving components of physical fitness, such as strength, power, balance and agility. It has been shown in other sports that performing exercises to improve these components before you begin training or playing matches may lower the likelihood of injury. We would like to see if this is also possible in rugby.

What does the study involve?
We will visit your school at the beginning and at various points throughout the season. On the first visit, we will teach your coaches a structured warm-up that they will then ask you to perform before your school rugby training sessions and matches during the season. We will also take some measurements of your height and body mass. Also, during the season:
- Your coach will record the amount of time you spend rugby training and playing in rugby matches.
- Details of any injury you get in rugby matches or training which cause you to miss a day's training will be recorded by your school doctor/nurse/physiotherapist.

This information will be analysed by researchers at the University of Bath.

Whom are we asking to take part?
All rugby players in U15-U18 squads in English schools.

Do I have to take part?
It is up to you whether you take part in the study. You do not have to take part but the more players who take part, the more we will find out about whether the warm-up we give you reduces the number of injuries that occur. If you want to take part, you must sign a consent form that confirms you have read this information and you agree to be included in the study. You can withdraw from the study by contacting us at any time without giving a reason.

What do I have to do?
We will visit your school at the beginning of the season, and we will perform some simple measurements of your standing height, body mass, and body composition, as well as recording some information relating to how old you are, which position you play, and any previous injuries you have had.

Are there any risks from taking part?
The measurements we will take are not tiring and so the risks of you being injured are very low.

Will information about me be kept confidential?
The Data Protection Act says that we must have your permission to collect information about you during this study. All information collected is stored using a code number rather than your name.

What will happen to the information from the study?
The information will be analysed by researchers at the University of Bath. We will produce a report about the warm-up and its effects on injuries in youth rugby. No personal references will be made in any report.

RFU Youth Rugby Study (FMC: RUGBY) 2015/16
Player Information Sheet & Consent form

Player consent form

I have read and understand the information about this study and I have had a chance to ask questions.

I agree to take part in the study, and that the information collected about me will be used only for research purposes and in a report to my school/club.

I understand that I can withdraw from this study at any time without being asked why.

Participant:

_____   _____   _____
Name   Date   Signature

For participants aged under 18 years on the first day of the playing season:

Coach (in loco parentis):

_____   _____   _____
Name   Date   Signature

For participants who turn 18 years during the study period to re-consent to participation:

_____   _____   _____
Name   Date   Signature

Research taking consent:

_____   _____   _____
Name   Date   Signature

In the event that you longer wish to participate in the study at a later date, please tick one of the boxes below:

I am happy for any prior data collected from me to be used by the   ☐
researchers

I am not happy for any prior data collected from me to be used by the researchers   ☐

<u>OFFICE USE ONLY</u>

SCHOOL   [   ]

PLAYER PROJECT ID   [   ]

PLAYER SEASON ID   [   ]

APPENDIX C: PARTICIPANT (COACH) INFORMATION AND CONSENT FORM (CHAPTER FIVE)

UNIVERSITY OF BATH

Direct Line: +44 (0)1225 384176
Fax: +44 (0)1225 383275
E-mail: m.d.hislop@bath.ac.uk

FMC: Rugby Project – Participation Agreement

Thank you for your interest in taking part in this research study. We would like to make sure that all parties are aware of the aims of the project, the support your school will receive from the research team as it participates, and also the commitment that the school is entering into.

Background to the study
Injuries are an unfortunate part of sport for youth athletes, and rugby is no different. However, some injuries may be preventable and one way of attempting this is to try to improve the physical readiness of the players. Structured exercise programmes which combine components of physical fitness, such as strength, power, balance and agility can be used to try and improve the movement patterns of players. We would like to evaluate whether certain pre-activity exercise programmes can reduce the risk of injury for school rugby players in the U15-U18 age groups.

Benefits of taking part in this study
Taking part in this study will provide your sports programme with an opportunity to demonstrate a duty of care to both pupils and parents, and to join a community of schools that are proactively involved in using strategies designed to reduce injury risk in school sports. Your sports programme will also benefit from gaining access to cutting-edge physical preparation resources.

Support from the Research Team
- Organising and running 'coach the coaches' sessions during the summer term to prepare rugby coaches to be able to deliver the 'pre-activation' exercises.
- Distributing all data collection and exercise programme materials to school staff in the summer term.
- Visiting the school to collect all completed paperwork and help with enquiries every two weeks.
- Ad-hoc visits to the school to meet with the director sport / director of rugby / medical centre representative to provide project support whenever requested.
- Liaising regularly with the Director of Rugby and medical centre through email or phone to provide support as and when required.

Commitment of School Staff

Should you wish to take part in this study, you would be committing to:
- Providing current contact details for senior staff (director of sport and director of rugby) and medical centre (nurse / doctor / physiotherapist) to the research team.
- Providing the parents/legal guardians of players with access to the parental opt-out form (either through email or through uploading the form to the school web page).
- Attending a 'coach the coaches' session during the 2014 summer term where you will be given the initial set of exercises by the research team.
- Beginning each training session and match preparation by completing pre-activation exercises.
- Rugby coaches for all U15-U18 teams completing a short weekly report form for their teams (5 minutes)
- Medical centre staff completing a short injury report form for injured players (3 minutes per injury)
- Graduate sports assistant (where available in school) to collect and collate all completed report forms for bi-weekly collection by the research team data collection assistant.
- Director of sport, director of rugby, and a medical centre representative to meet with the research team on four occasions during the winter term (twice per half-term) to discuss study progress and address any outstanding issues.
- Contacting research team as soon as any issues become apparent.

I understand the objectives, commitment and support available from participating in this project. I hereby consent to participate in this study.

Head teacher: _____ _____ _____
              (Signature)   (Print Name)   Date

Director of Sport: _____ _____ _____
                  (Signature)   (Print Name)   Date

Director of Rugby: _____ _____ _____
                  (Signature)   (Print Name)   Date

Medical Centre
Contact: _____ _____ _____
         (Signature)   (Print Name)   Date

APPENDIX D: BASELINE COACH QUESTIONNAIRE (CHAPTER SIX)

FMC: Rugby 2015-2016
Coach Survey

School Code ☐☐☐   **Response Code** ☐☐☐

Thank you for agreeing to complete this survey. This survey has been designed as part of the FMC: Rugby project being conducted by the University of Bath on behalf of the RFU. You have been invited to complete this survey because your School's rugby programme has agreed to be involved in the FMC: Rugby project. The information you provide will remain strictly confidential.

This survey should take you approximately 10 minutes to complete. Please answer all questions thoughtfully and as accurately as possible. If you have any questions regarding this questionnaire, please contact Mike Hislop at rfu-youth@bath.ac.uk.

SECTION A

<u>Instructions:</u> Please answer the following questions and provide brief details where appropriate.

1. Which role(s) will you be responsible for at your school during the 2015/16 academic year? (Please tick all answers that apply below):

   ☐ Senior management (Head teacher / Principal, Deputy head teacher, Assistant head teacher)

   ☐ Subject leader (Head of Department, Head of Faculty, Curriculum Co-ordinator)

   ☐ Co-curricular director/ Co-ordinator (Director/ Head of Sport, Rugby, Cricket, Hockey, Music, Drama, etc.)

   ☐ Classroom teacher

   ☐ Other, please specify: _____

2. Which age group are you coaching during the 2015/16 academic year? (Please tick)

   ☐ Under 15

   ☐ Under 16

   ☐ Under 18

3. How many years have you been involved in rugby coaching? (Please tick):

   ☐ Less than 1 year
   ☐ 1-3 years
   ☐ 3-5 years
   ☐ More than 5 years

4. Which age groups have you coached previously during your career? (Please tick all that apply):

☐ Mini (Under 7-Under 8)
☐ Midi (Under 9-Under 12)
☐ Youth (Under 13-Under 18)
☐ Adult

5. What is the highest level of rugby participation at which you have coached? (please tick the option that most accurately reflects your answer):

☐ School / Club
☐ Sub – county (eg: Cambridgeshire, Northamptonshire, etc.)
☐ County / Constituent body (eg: Somerset, Warwickshire, etc.)
☐ Divisional (eg: South West, London & South East, etc.)
☐ International (eg: England, Wales, etc.)

6. Do you have a **formal rugby coaching qualification** (eg: RFU Level 1, 2, etc.)? If so, please describe your highest level of qualification, and certifying organisation.

☐ No

☐ Yes, please describe briefly: _____

7. Do you have a **medical or first aid certificate** or a formal qualification? If so, please describe your highest level of qualification, and certifying organisation.

☐ No

☐ Yes, please describe briefly: _____

8. Have you ever used a specific conditioning programme with your teams at training sessions to **reduce the risk of injuries** among your players?

☐ No

☐ Yes, please describe briefly: _____

Instructions: Please answer the following questions and provide brief details where appropriate.

1. In your opinion, the **overall injury risk** in youth rugby is (please circle one):

Low	1	2	3	4	5	High
	Very	Quite	Neither	Quite	Very	

2. In your opinion, how serious are the following types of rugby injury?

	Not at all serious		Moderately serious		Very serious
Cervical spine / neck injury	1	2	3	4	5
Knee ligament injury	1	2	3	4	5
Thigh muscle strain	1	2	3	4	5
Bone fracture	1	2	3	4	5
Shoulder joint injury	1	2	3	4	5
Contusion / haematoma / bruise	1	2	3	4	5
Concussion	1	2	3	4	5

3. How preventable do you think muscle injuries (ie: tears, strains) are (please circle one)?

Unpreventable	1	2	3	4	5	Preventable
	Very	Quite	Neither	Quite	Very	

4. How preventable do you think bone-related injuries (ie: fractures, stress fractures) are (please circle one)?

Unpreventable	1	2	3	4	5	Preventable
	Very	Quite	Neither	Quite	Very	

5. How preventable do you think ligament injuries (ie: sprains, tears, ruptures) are (please circle one)?

Unpreventable	1	2	3	4	5	Preventable
	Very	Quite	Neither	Quite	Very	

6. Overall, how **preventable** do you think rugby injuries are (please circle one)?

Unpreventable	1	2	3	4	5	Preventable
	Very	Quite	Neither	Quite	Very	

FMC: Rugby 2015-2016
Coach Survey

School Code ☐☐☐   Response Code ☐☐☐

Instructions: Please take a few minutes to tell us what you think about completing the **RFU-Activate programme with your team.** There are no right or wrong responses; we are merely interested in your personal opinions.

1. How confident are you that you **understand** the RFU-Activate programme well enough to use it with the team(s) you are coaching during the winter term?

Unconfident	1	2	3	4	5	Confident
	Very	Quite	Neither	Quite	Very	

2. How confident are you that you **have the ability** to use the RFU-Activate programme with the team(s) you are coaching in the upcoming winter term?

Unconfident	1	2	3	4	5	Confident
	Very	Quite	Neither	Quite	Very	

3. If the players on your team did not enjoy performing the RFU-Activate programme, how likely would it be that you could still have them continue to use the RFU-Activate programme for the winter term?

Unlikely	1	2	3	4	5	Likely
	Very	Quite	Neither	Quite	Very	

4. If completing the RFU-Activate programme was too time consuming, how likely would it be that you continue to do use the RFU-Activate programme for the winter term?

Unlikely	1	2	3	4	5	Likely
	Very	Quite	Neither	Quite	Very	

5. If the RFU-Activate programme did not contain enough rugby-specific exercises, how likely would it be that you continue to use the RFU-Activate programme for the winter term?

Unlikely	1	2	3	4	5	Likely
	Very	Quite	Neither	Quite	Very	

6. Imagine that your team regularly completes the RFU-Activate programme at games and training sessions. If you missed completing the RFU-Activate programme at a match or training session, how likely would it be that you could start completing it again at the next session?

Unlikely	1	2	3	4	5	Likely
	Very	Quite	Neither	Quite	Very	

7. How sure are you about ...

a. Teaching the RFU-Activate programme to the players on your team?

Unsure	1	2	3	4	5	Sure
	Very	Quite	Neither	Quite	Very	

b. When to have your team complete the RFU-Activate programme?

Unsure	1	2	3	4	5	Sure
	Very	Quite	Neither	Quite	Very	

8. How sure are you about ...

a. Dealing with challenges in order to stick to your intentions of completing the RFU-Activate programme?

Unsure	1	2	3	4	5	Sure
	Very	Quite	Neither	Quite	Very	

b. Encouraging your team to perform the RFU-Activate programme to the best of their ability?

Unsure	1	2	3	4	5	Sure
	Very	Quite	Neither	Quite	Very	