IDENTIFYING RISK FACTORS FOR SEVERE INJURIES IN RUGBY PLAYERS

REZVAN MIRSAFAEI RIZI

Ph.D

The Hong Kong Polytechnic University

2017

The Hong Kong Polytechnic University

Department of Rehabilitation Sciences

Identifying Risk Factors for Severe Injuries in Rugby Players

Rezvan Mirsafaei Rizi

A thesis submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy

January 2017

CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

____________________________ (Signed)

Rezvan Mirsafaei Rizi (Name of student)

Abstract of thesis entitled

"Identifying risk factors for severe injuries in rugby players"

Submitted by Rezvan Mirsafaei Rizi

for the degree of Doctor of Philosophy

at the Hong Kong Polytechnic University in January 2017

The game of rugby is physically demanding with many physical collisions and tackles leading to musculoskeletal injuries. The players require not only a wide range of individual skills but also well-developed fitness qualities. The role of physical fitness however, in the prevention of injury is not well understood. Due to the high incidence of severe injuries and the consequences, it is critical to identify risk factors to develop adequate injury prevention strategies. Therefore, the purpose of this study was to determine the influence of physical fitness parameters on the risk of severe injuries in rugby players in different levels of play and in different formats.

Two prospective studies were conducted in this study. In season 2014-15, a study was conducted to amateur athletes on rugby-7s teams which included 104 university rugby players (90M : 14F) aged 20.6 ± 1.9 years (mean ± SD). For season 2015-16, another study was conducted on 135 rugby-15s players which included 74 semi-professional players (47M: 27F) and 61 amateur players (44M: 17F) aged 24.1 ± 4.00 years. Players underwent pre-season assessments of power, strength, speed, agility, endurance, stability and flexibility. Throughout the season, rugby-related injury and exposure data were collected. Potential predictor variables were analyzed using Cox regression model to identify risk factors associated with severe injuries (time loss > 28 days).

The findings of the study revealed that the incidence of severe injuries for the match in amateur rugby-7s players was 22.2/1000 player hours and in rugby-15s was 14.7 and 12.8/1000 player hours for amateur and semi-professional players respectively. For amateur rugby 7-s players, female gender (adjusted hazard ratio [HR] = 8.35; 95% confidence intervals [CI] = 2.01-34.8), slower (adjusted HR = 3.51; 95% CI = 1.17-10.5) and less agile (adjusted HR = 2.22; 95% CI =1.26-3.92) players as well as players with hip flexors tightness (adjusted HR = 1.12; 95% CI = 1.00-1.25) were at significantly greater risk of sustaining severe injuries. For amateur rugby-15s players, those with greater body weight (adjusted HR = 6.84; 95% CI = 1.8-26.3) and poorer balance ability (adjusted HR = 4.38; 95% CI = 1.1-17.9) were at significantly higher risk of severe injuries. There was no significant predictor for severe injuries in semi-professional players. These findings highlight the importance of pre-season screening for amateur players to identify athletes who are at higher risk of injury; that may have implications towards injury prevention. The development of gender-specific injury prevention measures that emphasize speed and agility for rugby-7s players and balance training for rugby-15s players may be important to reduce the risk of severe injuries.

PUBLICATIONS

Conference presentation:

Mirsafaei Rizi R, Yeung EW, Yeung SS, Stewart N. Identifying risk factors for injuries in university rugby players. 10th International Society of Physical and Rehabilitation Medicine World Congress, May 29-June 2, 2016, Kuala Lumpur, Malaysia, pp.806.

Refereed paper:

Mirsafaei Rizi R, Yeung SS, Stewart NJ, Yeung EW. Risk factors that predict severe injuries in university rugby Sevens players. Journal of Science and Medicine in Sport 2017; 20:648-652.

ACKNOWLEDGMENTS

I would like to express my gratitude to a number of people who have enabled me to complete my Ph.D. study:

My thanks to Professor Ella Yeung, my chief supervisor, for her expert guidance and continuous support, especially for her patience while attending to me throughout this research – I will never be able to reveal how much I appreciate you.

Thanks to Dr. Simon Yeung, my co-supervisor, for his guidance and support that made this research project possible.

Thanks to Mr. Nathan Stewart, my co-supervisor, whose door is always open to answer my questions and gave me guidance on this project.

Thanks to Dr. Raymond Chung, for assistance with the statistical analyses of results used in this study.

Thanks to Mr. Siu Sik Cheung and Mr. Thomas Chan, for administrative assistance throughout the research process.

Thanks to the Hong Kong Rugby Union, athletes, coaches, physiotherapists and students for taking the efforts to make this research project become a reality.

Thanks to my friends especially Chad and Ebi for their encouragement and constant support, especially during the hard times.

Thanks to my family: Mum, Dad, my dear sibling, Razyieh, Ramin and Behnam, for your ongoing love and support as I ambitiously pursue my aims. Finally, to dear Ehsan, I honestly do not know how I would have done it without you. I love you so much.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

LITERATURE REVIEW

1.1 INTRODUCTION

Rugby has been recognized as one of the world's top team sports with participation of 6 million players over 120 countries. The International Rugby Board reports that rugby is in a new stage of development in 205 countries. Rugby union (Sevens) was selected for inclusion as an Olympic sport held in Rio in 2016 (Wilson *et al.*, 2013). The highly physical nature of rugby makes it different from other popular contact sports. Apart from the high-intensity activity such as running, sprinting, rugby play also involves unprotected contacts and physical collisions during tackling, rucking and mauling. Thus, different physical components are needed for rugby players including strength and power, stability, speed and agility as well as endurance. When compared with other sports, rugby has a significantly higher injury incidence. An injury surveillance in 2005-2006 showed that the overall injury rate for high school boys rugby players was higher than the football players (4.9 injuries *vs*. 4.4 injuries per 1,000 player exposures respectively). This pattern was similar in girls with 2.7 injuries for rugby players *vs*. 2.4 injuries per 1,000 player exposures in football players (Collins *et al.*, 2008). A recent prospective study conducted for American collegiate football and rugby players over three seasons revealed that the overall injury rate for rugby was 3.1-fold higher than that of football (15.2/1000 *vs*. 4.9/1000 player exposures). Furthermore the injury rate of ligament sprains, contusions, fractures and concussions in rugby were 2-4 times higher than those in football (Willigenburg *et al.*, 2016).

At the professional level, the injury incidence ranges from 2-6/1000 player hours for training and 27-218/1000 player hours for matches (Williams *et al.*, 2013). For semi-professional players, the incidence ranges from 21.7-54.1/1000 player hours for matches (Schneiders *et al.*, 2009; Roberts *et al.*, 2013; Smith *et al.*, 2015). At the amateur level, the incidence ranges from 4.28-5.5/1000 player hours for training (Junge *et al.*, 2004; Kerr *et al.*, 2008) and 16.6-93 per 1000 player hours for matches (Takemura *et al.*, 2009; Chalmers *et al.*, 2012; Roberts *et al.*, 2013). Furthermore, it has been reported that rugby injury incidence had doubled over the last 40 years, likely to be attributed to the increased speed and intensity of play (Garraway *et al.*, 2000). Of particular importance, severe injuries resulting in irreversible and permanent damage are reported for the game of rugby. A study conducted on spinal cord injuries occurred between 1980-2007 in South African rugby showed a trend of increase in numbers. For those players with spinal cord injuries, 61% had a catastrophic end after 12 months, including 8% who died through that time (Hermanus *et al.*, 2010). Furthermore, the economic impact of these injuries is of significance. For instance, the New Zealand Accident Compensation Corporation revealed estimated the financial cost of rugby injuries in season 1999 amounted to $21.5 million, which is ~25% the total cost to the Corporation's Sport and Recreation Fund (Beardmorea *et al.*, 2005).

Because of these concerns to the players' health and the financial consequences, it is therefore of paramount importance to identify injury risk factors for formulation of injury prevention policies. The development of screening tools should be the first step in injury prevention. Some risk factors have been prospectively reported in studies at the club and professional-level level. These include previous injury, training volume, body mass index, ligament laxity, cigarette smoking status, years of rugby experience, stress, age, weather and ground conditions, the level of play, time of the season and foul play (Quarrie *et al.*, 2001; Brooks & Kemp, 2008; Chalmers *et al.*, 2012). However risk factors associated with different level of competitions in different playing formats are not clear. The current study aims to investigate the incidence of injury and the associated risk factors for different competitive levels (amateur *vs*. semi-professionals) and playing formats (7s *vs*. 15s).

1.2 THESIS OVERVIEW

Chapter 1 presents the overall framework of this study. This includes a thorough literature review on the injury epidemiology for rugby union, the nature of the game including physical demands of the game, injury incidence, injury mechanism, risk factors and the rationale to conduct the present study. Chapter 2 provides the general methodology of the two studies including recruitment of players, preseason assessment tools, and injury surveillance. The results of university amateur rugby-7s players and the results of community rugby-15s players (amateur and semi-professional) are described respectively in Chapter 3 and 4. Chapter 5 summaries the critical issues of the results and integrates key findings from each chapter. Conclusions and recommendations for future study are presented in Chapter 6.

1.3 RUGBY UNION OVERVIEW

The game of rugby was formed in 1823 when William Webb Ellis, a student at the rugby school in England, disregarded the rule of soccer and ran down the field to score while taking the ball in his hands (Morrison, 1993). Rugby splits into two different codes in 1895: rugby union and rugby league. Rugby league was always professional whereas union was at amateur level until it became professional in 1995.

The rules and the number of players are different. Rugby league includes 13 players, which is more structured, and is played mostly in United Kingdom, France, Australia and Oceania. Rugby union consists of 15 players and is now played more widely in the world (Mužek, 2015).

Today rugby is recognized as one of the most popular contact sports played in many countries around the world. The two main types of rugby union are Fifteens and Sevens. Rugby-7s (shorted form of rugby-15s) is different in the number of players compared with rugby-15s (7 *vs*. 15) and also the duration of the match (7 *vs*. 40 min halves). However, the size of the field is the same. As such, the physical demands of rugby-7s is naturally higher than those in rugby-15s (Wilson *et al.*, 2013).

Rugby is played at different levels. At the club level, it is subdivided into various levels including professional, semi-professional, and amateur. While for professional rugby players, rugby is a full-time profession, but for semi-professional player, they receive a regular salary from their teams but at a lower rate than a full-time professional player and also rely on additional employment to generate income. Amateur players participate without any remuneration (Brooks & Kemp, 2008). Professional and semi-professional players compete at a higher standard of play. In Hong Kong, the national governing body for rugby is Hong Kong Rugby Union (HKRU). HKRU was established in 1952 and from the year 1988, it becomes a branch of World Rugby (formerly the International Rugby Board). HKRU coordinates all the domestic leagues for different ages, genders, and levels as well as world-renowned Hong Kong Sevens (HKRU, 2016a). The Premiership and the Premiership A teams are at the top levels of competition in th55instinste community. With the increasing interest in rugby, univeristy teams were formed and become members of the University Sports Federation (USF) (HKRU, 2016b).

1.3.1 Players' profile

Because of the different demands, the physique of the rugby-15s players at different playing positions are different. The forwards are significantly heavier (males - forwards: 98.5 *vs*. backs: 81.8 kg, females - forwards: 78.9 *vs*. backs: 62.9 kg) and taller (males - forwards: 186 *vs*. backs: 177cm, females - forwards: 165 *vs*. backs: 160cm) than the backs (Quarrie *et al.*, 1995; Rienzi *et al.*, 1999; Hene *et al.*, 2011). They tend to have great upper body strength (push up: 44 *vs*. 36 repetitions) and more powerful leg muscles (vertical jump: 50 *vs*. 44 cm) to drive themselves forward (Quarrie *et al.*, 1995). The shorter and smaller frame of the backs enable them to move faster (40m speed: backs: 5.9 *vs*. forwards: 6.5 s) (Hene *et al.*, 2011). Controlling the ball and balance are important skills for the backs that perform pass and tackle at high speed. They also need calmness and coordination to kick and catch the ball under considerable pressure (Wilson *et al.*, 2013). In rugby-7s, since set plays (a condition when the ball is returned to open play following a stoppage) are scaled down and less frequent than rugby-15s, so 7s forwards players are less heavy (rugby 7s: 68 *vs*. rugby 15s: 78.9 kg) (Hene *et al.*, 2011; Ma *et al.*, 2016), and are faster and more agile. In addition to covering vast amounts of ground at quick acceleration, 7s backs players must be able to open up opponent teams with creative passing and running (Wilson *et al.*, 2013).

1.3.2 Playing position

Rugby-15s includes eight forwards and seven backs. The forwards are made up of two props and a hooker; second row (two locks); two flankers and a number eight. In the backs, the scrumhalf follows the ball and passes it to the forwards and the backs. The playmaker of the team is fly half, this player starts the moves and usually does most of the kicking. The defensive heart of the back are two centers. The wingers and full back tend to be more elusive and speedy players, and they are the last line of the defense. Rugby-7s involves three forwards (prop and hooker), three backs (fullback, center, and fly half) and the scrum-half (Wilson *et al.*, 2013).

1.3.3 Rugby skills

Particular skills in rugby includes play involving tackle, ruck, maul, scrum, lineout, passing and receiving the ball, and point scoring. Other general sports skills required to play rugby include running, jumping, throwing, catching and kicking.

Tackle is the most important and repeated contact skill in the rugby union. Tackle aims to regain the possession of the ball (Figure 1.1). Around 140-300 tackles per match can be happened by one or more tacklers (Quarrie & Hopkins, 2008; Roberts *et al.*, 2015). By definition, a tackle takes place when the ball carrier is controlled by one or more opponents and is brought to ground (World Rugby, 2015). However, more general tackles are recognized when a player attempts to hold the ball carrier and prevent his movement.

The ruck is formed when a player is tackled to the ground. The player should release the ball immediately, and the offensive team will try to stop the defensive team from obtaining possession of the ball (Figure 1.1). The world rugby laws of the game state that the ruck is a phase of play during one or more players from each side close around the ball on the ground while being on their feet. Players must use their feet to pass the ball or drive over it at which point it can be picked up. Whichever team is positioned over the ball is considered in possession of the ball (World Rugby, 2015).

Maul is similar to ruck, but maul occurs when the ball is contested with the ball carrier staying on his feet instead of contesting the ball on the ground (Figure 1.1). A maul forms when one or more opponents hold a player carrying the ball and the ball carrier is bind with one or more teammates (World Rugby, 2015).

Scrum is used to restart play quickly after a minor infringement or a stoppage (e.g. forward pass). A scrum is formed when eight forwards from each team (three forwards for rugby-7s), bound together in three rows on each side and creates a tunnel (Figure 1.1). Then the scrum half player throws the ball so that front row players can hook the ball behind them with their feet for possession and make it available to play (World Rugby, 2015).

Lineout is set up to restart play while the ball moves out of the field. A minimum of two players from each team needs to form a lineout. The throwing team determines the maximum number of players required in the lineout. The players form two parallel lines, then one player throws the ball into the line, the jumper player is allowed to catch the ball and is supported by other players (Figure 1.1) (World Rugby, 2015).

Figure 1.1 Rugby skills: a. tackle; b. ruck; c. maul; d. scrum; e. lineout

1.4 PHYSICAL AND PHYSIOLOGICAL DEMANDS OF RUGBY

1.4.1 Energy sources

Rugby requires both aerobic and anaerobic systems of energy (Duthie *et al.*, 2003). Skills such as rucking and tackling are done at a high speed whereby the anaerobic system typically provides energy for the muscles, whereas, during recovery and repeated efforts such as jogging, the aerobic system supplies the needed energy (Pook, 2012; Chiwaridzo *et al.*, 2016). In rugby union, maximal aerobic capacity (VO_{2max}) was evaluated by yo-yo intermittent recovery test. The adequate aerobic ability of rugby players has been suggested to be between 50-60 $ml.kg^{-1}.min^{-1}$ (Darrall-Jones *et al.*, 2015; Chiwaridzo *et al.*, 2016).

1.4.2 Strength and power

Tackling, being tackled, scrum, ruck and maul all require maximal efforts that challenge the power and strength of the players. These are full body actions that require high levels of strength in different planes of movement. Power is also required to break tackles, to form tackles and jump for the ball (Pook, 2012).

Leg power is required in jumping in the scrum and line-out. Vertical jump test has frequently been used to assess leg power with the suggested range to be from 45-65 cm in rugby players (Nicholas, 1997; Quarrie *et al.*, 2001; Shaji & Isha, 2009). Muscular power was measured in the upper body using isometric mid-thigh pull test with a score of 265.4 ± 27.8 kg for rugby players (Darrall-Jones *et al.*, 2015). Push up test was recognized as one of the variables that best discriminate between backs and forwards rugby players. The upper body strength is within a range of 18-67 repetitions

(Carlson *et al.*, 1994; Durandt *et al.*, 2006). In order to assess hip adductor strength, squeeze test was used in elite junior rugby union players with a reported average of 228.3 ± 37.9 mmHg (Coughlan *et al.*, 2014a). Single leg bridge test was recognized as a significant predictor of hamstring injury in Australian football players; players with low hamstring muscle strength with average of 20.3 repetitions were at more risk of hamstring injury compared with uninjured players performing an average of 25.98 repetitions (Freckleton *et al.*, 2013). The basic plank test and side plank test were used to assess core muscle strength. The norm for athletes was determined as 123 ± 69 s for basic plank test (Strand *et al.*, 2014) and for side plank test it was determined as 103.0-104.8 s (Anderson *et al.*, 2014). To assess the strength of neck flexors, neck flexor muscle endurance test was recognized as a reliable test with the average score of 20.9-54.1 s hold (Edmondston *et al.*, 2008; Juul *et al.*, 2013).

1.4.3 Stability and balance

The need for maintaining stability to support the joints, including shoulders, knees, neck, back and pelvis, during impacts is particular important for rugby. Stability is necessary for effective force transferring from the ground up throughout contact phases (tackling, ruck, and scrum) (Gamble, 2004). Dynamic balance was previously estimated using Y balance test (Coughlan *et al.*, 2014b). Y balance test has been used as a predictive measure of injuries in football players. Significant differences was observed between the injured and non-injured players in the composite scores (75.7 ± 9.05 *vs*. 71.4 ± 7.71 cm) (Pollock, 2010). Single leg hop test was used as physical performance for measure of knee stability. In rugby players, this test has been used to examine the biomechanical symmetry (Marshall *et al.*, 2015). The range of distance was 81-188 cm (Manske *et al.*, 2003).

1.4.4 Speed and agility

Speed and agility are important domains where quick changing in direction is needed when acting to the defender position, or decelerated fast to hit a ruck effectively or to accelerate to make or stop a tackle (Smart, 2011; Pook, 2012). These skills empower players to move immediately to position themselves in attack and defense (Austin *et al.*, 2011; Pook, 2012). Skilled rugby players reach their maximal velocity between 30 and 40 m (Barr *et al.*, 2013). Very seldom the sprint distance of more than 40 m is required in a single session of severe activity (Gabbett, 2005). Thus speed is usually conducted between 5 to 50 m (Vaz *et al.*, 2014). The average time for 40 m speed test for rugby players was reported to be 5.43 - 6.51 s (Hene *et al.*, 2011; Darrall-Jones *et al.*, 2015). The agility of rugby players have been evaluated using Illinois test, the average score for this test range from 15.10-20.30 s (Maria van Gent & Spamer, 2005; Durandt *et al.*, 2006; Jarvis *et al.*, 2009).

1.4.5 Flexibility

In rugby, flexibility of hamstring and lower back is often assessed using sit and reach test with a reported mean range of 39.9-44.2 cm (Maud, 1983; Maria van Gent & Spamer, 2005; Hene *et al.*, 2011). Thomas test was used to assess the flexibility of the iliopsoas muscle with reported average score to be 11.9 ± 5.6° in athletics (Harvey, 1998). Hip internal rotation test was used to measure prone hip internal rotation range of motion, the mean score for football players was identified as 67 ± 24.2° (Malliaras *et al.*, 2009). Bent knee fall out test is a reliable tool to measure the flexibility of hip adductors, the mean values were determined as 12.9 ± 5.1 cm for football players (Malliaras *et al.*, 2009). Dorsiflexion range of motion in ankle has been assessed by ankle dorsiflexion lunge test with the mean range of 13.9 ± 3.8 cm in a reliability study (Bennell *et al.*, 1998).

In addition, upper body flexibility is important for performing ruck and scrum (Lark, 2009). Shoulder internal and external rotation tests were used commonly. The total range of motion for rugby players was identified as 161.8 ± 12.9° (Fernández *et al.*, 2011). Reduced internal range of motion of shoulder was identified as a significant predictor of injury in professional rugby league players (odds ratio [OR] = 0.89) (McDonough & Funk, 2014).

1.5 INJURY INCIDENCE IN RUGBY

The present investigation follows the first two steps of the approach to sports injury risk management (Van Mechelen *et al.*, 1992) (Figure 1.2). In this 4-step model, establishing the injury incidence rate before identifying the mechanism and etiology of injury was recommended. This is then followed by implementation of a preventive measure and the effectiveness of the preventive measures is assessed by reevaluating the injury incidence (Van Mechelen *et al.*, 1992). The risk of injury is estimated by measuring the exposure time when the player participates in the sport (De Loës, 1997).

.

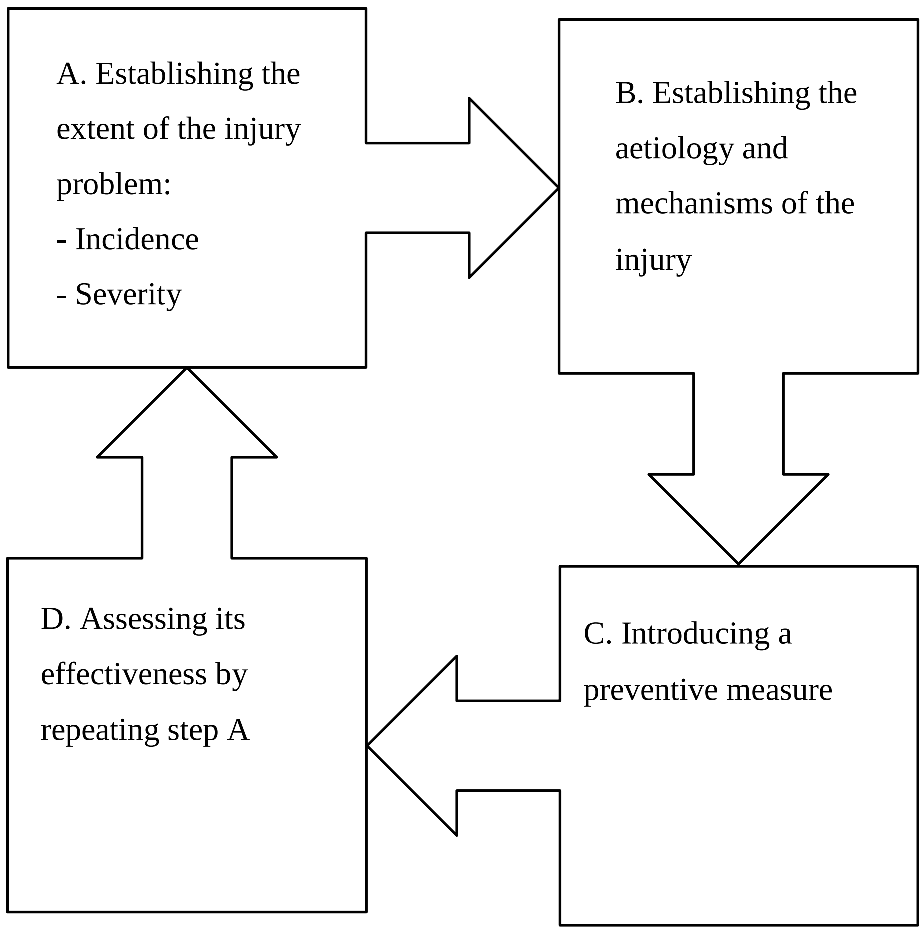

Figure 1.2 Four-step sequences for prevention of sports injuries

Injury incidence calculated as the number of injuries per 1000 hours of exposure has been suggested.

A study on the Australian rugby union players reported that the incidence of injury in rugby union before (1994-1995) was 47 per 1000 player hours, and after the start of professionalism (1996-2000), it was incresed to 74 injuries per 1000 player hours. This trend indicated a considerable increase of injury rate with increasing playing level (Bathgate *et al.*, 2002). The number of publications that studied rugby injuries has significantly increased since it turns to professionalism in 1995. Thus a unified way to report injury and the operational definition of injury is crucial to for accurate description of injury risk (Van Mechelen *et al.*, 1992). The difference in injury definitions and methodologies in the early studies of rugby union injuries make comparison of the results difficult. To have an agreement on the definitions and methods of recording and reporting of the injuries, the Rugby Injury Consensus Group (RICG) adopted a standardised definition of injury, training, and match exposure, recurrent injury, classifying injuries regarding location, severity, type, diagnosis and causation (Fuller *et al.*, 2007c). This consensus statement made the studies of injuries in rugby union more comparable. The group also recommended that the injury incidence of training and match should be reported separately because training exposure is greater than match, in particular at the professional level, as a result of this discrepancy, high extent of training exposure can conceal the high injury incidence incurred in match (Fuller *et al.*, 2007c).

An epidemiological study for different levels of rugby players showed that the largest proportion of injuries were related to match, and accounted for 80-90% of all injuries (Brooks & Kemp, 2008). After the Rugby World Cup of 1995; rugby union became professional, full-time training at the professional level has enhanced the development of fitness (speed, strength, power) as well as skill. As a result, the speed and force of contacts between players have also increased the ball-in-play time (19% per match) exposing players to more injuries (Brooks & Kemp, 2008). Furthermore, the change of rules lead to a more open game (Quarrie & Hopkins, 2007). It is not known however of the trend of match vs. training injury incidence at the amateur level.

In a meta-analysis that summarized epidemiological studies on incidence, severity and causes of injury of professional rugby (15 studies between 1995-2012), the overall injury incidence for matches was 81/1000 player hours, and 3/1000 player hours for training. The mean severity was 20 days for match and 22 days for training (Williams *et al.*, 2013). A study that examined English community rugby for semi-professional, amateur and recreational players reported the injury incidence. Any injury causing ≥ eight days from match play was recorded. The incidence was higher for semi-professional players (21.7/100 player hours) compared with amateur (16.6/1000 player hours) and recreational players (14.2/1000 player hours). The mean time-loss for all levels combined was 7.6 weeks' absence (Roberts *et al.*, 2013). Furthermore it was reported that that rugby played at professional level in England had the highest injury incidence (48/1000 player hours) (Brooks *et al.*, 2005a) which support that the incidence of injury increased at higher level of playing (Bird *et al.*, 1998; Quarrie *et al.*, 2001).

For semi-professional players, a prospective study reported the injury incidence was 54.1/1000 player match hours with median days of absence of 30 (Smith *et al.*, 2014). Another study using a different injury definition (medical attention or missed at least one scheduled training or match) reported the incidence to be 52/1000 player hours (Schneiders *et al.*, 2009). This injury incidence in comparison with a study conducted by Quarrie *et al.* (2001) ten years earlier using the same definition was less than half (54/1 *vs*. 106/1000 player hours). The difference might be related the reporting that both training and match injuries were recorded by Quarrie *et al.* (2001) whereas Schneiders *et al.* (2009) assessed injuries sustained during matches only.

For amateur players, the overall injury incidence of collegiate rugby union in Japan over one season was 48.4/1000 player hours with a mean severity of 25.2 lost days. Here, injury was defined as any events that stopped the player from taking part in the next scheduled training or match. The incidence of injury was higher in the college students at a senior grade (69.7/1000 player hours) when compared with students at a junior grades (32.1/1000 player hours) (Takemura *et al.*, 2009). These findings are consistent that the injury incidence was higher in senior grades as experience, fitness, skills, and intensity of matches were expected to be higher (Bird *et al.*, 1998; Quarrie *et al.*, 2001). The findings through another investigation on amateur club players indicated that the overall incidence of injury was 52.3/1000 match-hours exposure. Thirty-six percent all injuries led to more than one week time-loss from the play. The incidence rate of moderate and severe injuries with greater than one week time lost was 10.6 and 8.1/1000 player hours respectively (Swain *et al.*, 2016).

The epidemiology study on youth community rugby determined that overall incidence of match injury from age 9 to 17 was 24/1000 player hours. The results indicated that the injury incidence and severity of injury significantly increased by increasing age (Haseler *et al.*, 2010). The older players (16-17 years old) had a higher incidence of injury (49.26/1000 player hours) and experienced more severe injuries compared with junior players (12-17 years, 34.2/1000 player hours), and in the young age group (9-10 years old) where only minor injuries were identified.

As for gender differences, a descriptive epidemiological study collected data over five years from the men and women intercollegiate rugby players showed that the overall incidence rate of injuries in men was 30% higher than women (rate ratio = 1.3, 95% CI = 1.09-1.54). Furthermore, severe injury pattern was different between genders. Women players experienced 5.3 times more anterior cruciate ligament tear than men (rate ratio = 5.32, 95% CI = 1.33-30.5) whereas male players had 2.5 times more fractures. These differences are likely to be due to the differences in tackle, player size or speed (Peck *et al.*, 2013).

Rugby-7s players are exposed to faster speed and more forceful contacts. An injury rate of 55.4/1000 playing hours (injuries included both medical attention and time-loss) was reported at the amateur level (Lopez *et al.*, 2012). The injury incidence was lower than the findings from international rugby-7s players; the incidence of time-loss injuries was 106.2 injuries per 1000 player-hours. The means severity of injuries was 45 days with the median of 24 days (Fuller *et al.*, 2010c). Regardless of different definition for injury, the higher injury incidence at the elite level can be explained by higher competitive level than amateur rugby-7s players, or even than that reported for international rugby-15s (83.9-90.1/1000 player hours) (Fuller *et al.*, 2008; Fuller *et al.*, 2013; Fuller *et al.*, 2017). Furthermore, a prospective study on female rugby-7s players conducted over three years reported the overall injury rate to be 32.6/1000 player hours at the professional level and for 49.3/1000 player hours at the amateur level. The mean missed days for the professional players was 79.9 days per injury while for the amateur players it was 41.8 days (Ma *et al.*, 2016). Another prospective study on rugby-7s players included both male and female over three years. Increasing injuries in international rugby-7s players can be related to decreased set plays (scrum and lineout) and greater ball-in-play times with rugby-7s compared with rugby-15s (Ma *et al.*, 2016).

All in all, due to the difference in injury definition, it is difficult to make directional comparisons regarding injury incidence rates between these studies. Furthermore, the indication of the range of incidence among those levels may not be accurate. The vast extent of injury incidence rates highlighted the importance of applying uniform injury definition in reporting injury incidences for different playing levels, play format (15s *vs*.7s), gender and age.

1.6 SEVERITY OF INJURIES

Injury severity is usually defined by the time lost from training or match play. Similar to injury incidence, it can be defined as either the number of missed days or the number of missed games. For instance, severity for missed days can be defined as follows: $\leq$ 1 week as mild, 1-3 weeks as moderate and $\geq$ 3 weeks as severe or major (Brooks *et al.*, 2005a; Brooks *et al.*, 2005c). Also, severity can be defined as the number of missed games; injury with missing one game was mild, missing 2-3 games was moderate and severe injuries led to missing $\geq$ 3 games (Bathgate *et al.*, 2002). In yet another classification, injuries were classified as mild when a player left the field or missed a game or both (Best *et al.*, 2005). Based on RICG agreement (Fuller *et al.*, 2007c), injury severity was grouped as slight (0-1 days absent), minimal (2-3 d), mild (4-7 d), moderate (8-28 d) and severe (> 28 d). This agreement made the studies more comparable.

An epidemiology study indicated that most injuries were estimated to be slight to mild (≤ 1week) (64-82%), followed by moderate (1-3 weeks) which accounted for 10-18% and severe injuries (≥ 3 weeks) (8-22%) (Kaux *et al.*, 2015). In terms of playing level, the estimated average severity of injuries in professional rugby-15s players was 20 and 22 days lost for match and training respectively (Williams *et al.*, 2013). The mean severity of match injuries for community level of rugby-15s including both amateur player and semi-professionals was 53.2 days lost (Roberts *et al.*, 2013) while the mean severity for amateur players was 25.5 days lost (Takemura *et al.*, 2009). In the context of rugby-7s, the average severity for match was between 33-74.9 days lost (Fuller *et al.*, 2010c; Gabb *et al.*, 2014; Fuller *et al.*, 2016; Ma *et al.*, 2016) and for training it was 40 days lost in professional players (Gabb *et al.*, 2014). Amateur rugby-7s players sustained injuries with an average severity of 41.8 days lost (Ma *et al.*, 2016). In overall, a trend toward greater time-loss was seen among amateur players as well as rugby-7s players.

1.7 LOCATION, TYPES AND SEVERITY OF INJURIES

1.7.1 Lower limb injuries

A recent review of injuries in rugby union revealed that lower limb was the most common region of injury accounting to 30-55% of injuries (Kaux *et al.*, 2015). Apart from being the most frequent injury region, injuries to the lower limbs seem to be severe. In particular, knee injuries accounted for 21% of all days lost due to injury (Garraway *et al.*, 2000; Bathgate *et al.*, 2002; Dallalana *et al.*, 2007). Knee injuries sustained during the match (11/1000 player hours) had significantly higher incidence than training (0.16/1000 player hours). The most common knee injury was medial collateral ligament (MCL) (28.9% of all knee injuries). However, anterior cruciate ligament (ACL) injuries had the highest mean severity accounted for the greatest number of missed days. Chondral/meniscal injuries (18.5%), patellofemoral/extensor mechanism (12.3%) and posterior cruciate ligament (PCL) injuries (9.0%) were the other commons injuries (Dallalana *et al.*, 2007).

Thigh was the next common lower limb injury with the proportion of 13-19% of all injuries (Kaux *et al.*, 2015). The two most common injuries affected the thighs were hematomas and hamstring muscle injuries (Brooks *et al.*, 2006; Moore *et al.*, 2015; Palmer-Green *et al.*, 2015; Fuller *et al.*, 2016). About 37% of hamstring injuries were recognized as minor (≤ 1 week absent), 37% as moderate (1-3 weeks absent) and 26% as severe (≥ 3 weeks absent) (Brooks *et al.*, 2006).

Ankle injuries accounted for 15% of all training injuries and 11% of all match injuries. Lateral ankle ligament injuries were the most frequently reported ankle injuries in match and training while Achilles tendon injuries were the most severe injury. These two injuries together caused more than 50% of absence from training and match (Sankey *et al.*, 2008).

Foot injuries represented a small proportion of injuries accounted for 4% of all the injuries and resulted in 5% of the absence from training and match. The injury incidence sustained during the match was significantly higher than that for training (3.3 *vs*. 0.09/1000 player hours, $p < 0.001$). Sprain foot joint (20%) and foot contusion (14%) were the most common type of ankle injuries while stress fractures accounted for 8% of all ankle injuries but led to the most days absences (22%) (Pearce *et al.*, 2011).

1.7.2 Head and neck injuries

Head and neck (non-catastrophic) injuries are the next common region of injury accounted for 14-30% of all injuries (Kaux *et al.*, 2015). Concussions (Kerr *et al.*, 2008; Takemura *et al.*, 2009; Lopez *et al.*, 2012), lacerations (Bathgate *et al.*, 2002), and facial fracture (Kemp *et al.*, 2008) were the most common type of head and neck injuries. The overall injury incidence for head injury was reported to be 6.6 and 0.05/1000 player hours during match and training respectively (Kemp *et al.*, 2008). Further, rugby players were at a higher risk of concussion injures, in particular, while tackling or being tackled. Concussions accounted for 62% of all head injuries.

In the context of playing format (7s *vs*. 15s), concussion accounted for 5-9% of all injuries sustained during the match in rugby-15s and 2% of all match injuries in rugby-7s (Fuller *et al.*, 2015). The incidence of concussion injuries in rugby-7s was significantly higher than that in rugby-15s (risk ratio = 1.84) and also the severity of concussions was considerably higher in rugby-7s than rugby-15s with a mean severity of 19.2 and 10.1 missed days, respectively. Those players who started the game sustained the majority of concussions (rugby-7s: 91.2%, rugby-15s: 92.5%). Tackling was the main causes of concussion injuries in rugby-7s while collision was the major reason for concussion in rugby-15s (Fuller *et al.*, 2015).

1.7.3 Upper limb injuries

Injuries to the upper limb accounted for 15-20% of all match injuries in rugby (Kaux *et al.*, 2015). The injury incidence of upper limb ranged between 1.5-9.84 injuries/1000 player hours (Garraway *et al.*, 2000; Haseler *et al.*, 2010; Usman & McIntosh, 2013). Further, a significant association was reported between playing level and upper limb injuries. A lower incidence of upper limb injuries was reported for higher level of play. It has been suggested that lower physical fitness, experience, and skills may put the younger players in risk of injuries (Usman & McIntosh, 2013).

Regarding the type of upper limb injury, sprain/strain (55–71%) and dislocation or fractures (4–26%) were the most common ones (Bird *et al.*, 1998; Brooks *et al.*, 2005c; Usman & McIntosh, 2013). Fractures of hand/finger and dislocations of shoulder included 80% of the severe upper limb injuries (Bathgate *et al.*, 2002). Shoulder injuries have been reported as the most common site of injuries, accounting for 9–17% of all injuries (Usman & McIntosh, 2013). An explanation for the higher incidence of shoulder injuries than other upper limb injuries was that the shoulder is frequently involved in contact skills (Fuller *et al.*, 2010a). The incidence of injury to shoulder was reported within 1-4.9/1000 player hours in amateur players (Headey *et al.*, 2007; Kerr *et al.*, 2008; Haseler *et al.*, 2010) and 8.9/1000 player hours in professional players (Garraway *et al.*, 2000). The investigation into shoulder injuries reported that the incidence of match injuries was significantly more than training (8.9 *vs*. 0.1/ 1000 player hours) but injuries in training were more severe (61 *vs*. 27 absent days). The most common type of shoulder injuries was acromioclavicular joint injury (32% of all shoulder injuries) and rotator cuff injury (23% of all shoulder injuries), each one associating with 20% of days lost (Headey *et al.*, 2007).

1.7.4 Trunk injuries

Injuries to the trunk have been reported to account for 10-11% of all rugby union injuries. The severity of trunk injuries was nine missed days for rugby union players (Bathgate *et al.*, 2002; Brooks *et al.*, 2005c; Kaux *et al.*, 2015).

In summary, head, knees, thighs, ankles, and shoulders are the most commonly reported sites of injury. Soft tissue injuries including ligament sprains/tears, musculotendinous strains/tears, and contusions comprised more than 50% of all rugby-related injuries (Kaplan *et al.*, 2008).

1.8 CATASTROPHIC INJURIES

Although catastrophic events seldom occur in sport (Fuller, 2008), the long-term consequences and severity of these injuries make them the most disastrous injuries (Quarrie *et al.*, 2002). Studies have reported catastrophic neurological consequences and deaths in relation to spinal injuries in rugby (Quarrie *et al.*, 2002; Fuller, 2008). The findings of an investigation of catastrophic cervical spine injuries that was conducted for French rugby players showed that the cervical spine injury incidence had a declining trend over ten years (1996-2006). The injury incidence was 2.1/100,000 player per year during season 1996-97 and significantly decreased to 1.4 during the 2005-6 season. (Bohu *et al.*, 2009). The change of scrum rules improved playing welfare and has provided more safety for rugby players (Gianotti *et al.*, 2008; Trewartha *et al.*, 2015). Nevertheless, the result of a conducted study on amateur and professional rugby players in South Africa between 2008-2011, showed that the mean annual incidence of acute spinal injuries and brain injuries has remained at 2/100,000 player hours. In addition, the incidence of spinal injuries with permanent consequences (neurological deficit, quadriplegia or fatal) was significantly higher at the professional level than amateur level (4.25 *vs*. 0.24/100,000 player hours) (Brown *et al.*, 2013). Studies considering common injuries have indicated that increased speed, competitiveness, and aggressiveness may be responsible for the differences in incidences at higher levels of playing (Lee & Garraway, 1996; Bird *et al.*, 1998).

1.9 MECHANISMS OF INJURIES - CONTACT INJURIES

The mechanisms of injuries can be arised from contact and non-contact events. The majority of injuries (70-80%) at different levels and different format (7s or 15s) of rugby union occur in contact phases of play including tackle, maul, ruck and scrum (Lopez *et al.*, 2012; Roberts *et al.*, 2013; Kaux *et al.*, 2015).

1.9.1 Tackle

The risk of injury per tackle was significantly five times greater than any other contact events (Fuller *et al.*, 2007a; Brooks & Kemp, 2008; Fuller *et al.*, 2010c; Roberts *et al.*, 2015). Furthermore, tackle has been identified as the event leading to the highest injury incidence and greatest severity for both men and women players (Bird *et al.*, 1998; Kerr *et al.*, 2008). Over 50% of the reported injury attributed to contact injury especially tackle (McManus & Cross, 2004; Brooks *et al.*, 2005a; Brooks *et al.*, 2005c; Haseler *et al.*, 2010; Smith *et al.*, 2014). Tacklers are more likely to sustain upper limb injuries, especially shoulder and neck/head injuries, and ball carriers are at higher risk of injuries to the lower body (Fuller *et al.*, 2007a; Quarrie & Hopkins, 2008; Palmer-Green *et al.*, 2013; Roberts *et al.*, 2015). Incorrect skill has been identified as a risk factor for tackle injuries in youth athletes (Caine & Maffulli, 2005) thus training to improve skill for tacklers and ball carriers was an effort of injury prevention in amateur players (Quarrie *et al.*, 2007). In professional players, poor technique has also been suggested to be a contributing factor for injury. Hyperflexion of the cervical spine during contact seems to increase the risk of head and neck injuries (Quarrie & Hopkins, 2008). It has also been suggested that the ball carrier is at risk of severe injuries to the knees, ankles, and lower legs when the tackler jumps on the ball carrier while the ball carrier tries to continue running. Tacklers also sustain injury through this same mechanism but less frequent than ball carriers (Quarrie & Hopkins, 2008). The speed of the player, tackle height, tackle direction, and high impact force are some associated risk factors with tackle (Quarrie & Hopkins, 2008). It has been reported that younger players tended to stay on their feet more than professional players and involved in more passive tackles and thus safer than more experienced players (McIntosh *et al.*, 2010b). In the professional competitions, high-impact and high-speed tackles reported being associated with a greater risk of injury, particularly contact-type tackles with neck or head-to-head contact (Fuller *et al.*, 2007a; Quarrie & Hopkins, 2008).

1.9.2 Ruck and maul

While the frequency of tackles during a typical game had been reported to 221 events per game, ruck was reported to be the next common (142.5 event/game). The injury incidence for ruck ranged between 6-17% and for maul between 12-16% (Fuller *et al.*, 2007a). The results arising from the study of contact injuries showed that the most common injury sustained by ruck included calf muscle hematoma and foot/ankle ligament injury; and for maul, knee as well as foot/ankle ligament injury were the most common (Fuller *et al.*, 2007a).

The surveillance of injuries in English professional players revealed that ruck and maul caused the highest incidence and severity of injuries to the forwards because of their involvement in these phases of the game. Acromioclavicular (AC) joint and fractures of tibia or fibula bones in forwards and MCL injuries in backs had the highest incidence and absence from rugby training respectively during these skills (Brooks *et al.*, 2005b).

1.9.3 Scrum

Scrum has been suggested to be causing neck and back injury, particularly, the spinal cord (Caine & Maffulli, 2005; Fuller *et al.*, 2007b). Although, scrum caused fewer injuries (2-8%) (Fuller *et al.*, 2007a), a large proportion of spinal cord injuries (40%) was due to this skill (Trewartha *et al.*, 2015). Also, the mean severity of injuries caused by scrum was reported to be as high as 5.6 weeks missed for training/match (Roberts *et al.*, 2015). Front-row forwards were in greater danger as these players are exposed to the absorption and transition of higher forces in scrum (Quarrie & Wilson,

2000) than other forwards (Brooks *et al.*, 2005a; Kuster *et al.*, 2012). At the professional level, scrum-related cervical spine injuries were not as severe as the amateur players where poor skills can result in more injuries (Brooks & Kemp, 2008). The reason of cervical spinal cord injury has been reported to be extreme neck flexion, with or without rotation or hyperextension of the C4, C5, and C6 vertebrae. This mechanism occurs during the scrum that a front-row player can have the force of over 1.5 tons applied on their flexed cervical spine during scrum with the opposition (Kaplan *et al.*, 2008).

1.10 MECHANISMS OF INJURIES - NON-CONTACT INJURIES

1.10.1 Running

Although the injuries resulting from non-contact phases are not as frequent, but they also contribute to injuries. It has been documented that half of the non-contact injuries are running-related and occurred during training (Brooks *et al.*, 2005c; Moore *et al.*, 2015). Running constituted 4.5-11.3% of all injuries (Roberts *et al.*, 2013; Schwellnus *et al.*, 2014; Whitehouse *et al.*, 2016). Forwards significantly experienced a lower incidence of non-contact injuries than backs but a higher incidence of twisting/turning injuries (Roberts *et al.*, 2013). The most common non-contact injury was reported to be hamstring strain injury (56-68%) resulting in an average of 5.9 missed weeks (Brooks *et al.*, 2006; Roberts *et al.*, 2013). The higher incidence of non-contact injuries in backs could be because of the greater sprint and high-intensity running rounds engaged. Backs cover vaster distance than forwards at maximal speed

(Brooks *et al.*, 2006; Roberts *et al.*, 2013). For hamstring injuries, it has been reported that the injury occurred more frequently in the first match quarter (Roberts *et al.*, 2013).

An investigation on rugby-7s player showed that more injuries occur with tackle (40.4/1000 playing hours) than with running (6.9/1000 playing hours) (Lopez *et al.*, 2012).

1.10.2 Kicking

In rugby, kicks usually perform by backs particularly with scrum-halves, fly half and full backs during attack or defense (Biscombe & Drewett, 2010). Although more hamstring injuries happened during running, those resulting from the kicking phase were more severe (36 days lost) than that for all other events (Brooks *et al.*, 2006).

1.11 FOUL PLAY

Foul play has been defined as any intentional act in trying to cause harm to an opponent through forbidden activities (Comstock & Fields, 2005). Foul play was responsible for a high proportion of match injuries for men (4.5%) compared with women (1.9%) (Kerr *et al.*, 2008), and accounted to 6% of all injuries (Brooks *et al.*, 2005a). In addition, muscular contusions and head injuries including eyes and face happened more often due to foul play compared with non-foul play (Kaux *et al.*, 2015).

In summary, the high number of contact events reported per game (Fuller *et al.*, 2007a) confirmed the dynamic and physical character of the sport. Of note, the high frequency of tackle and ruck highlighted the significance of these phases of play. Despite lower incidence of injuries due to scrum and non-contact phases of play, they should not be taken lightly as the injuries are often of high severity resulting in more loss days.

1.12 INTRINSIC RISK FACTORS FOR INJURIES IN RUGBY

As the incidence of rugby injury is high, it is important to recognize the injury risk factors in order to develop effective injury prevention strategies (Brooks & Kemp, 2008). Risk factors for sports injuries can be classified as intrinsic (athlete-related) and extrinsic (environmental) risk factors (Van Mechelen *et al.*, 1992). Intrinsic risk factors predispose the athlete to injury and extrinsic risk factors modify the risk by making the athlete even more vulnerable to injury. These risk factors together make athletes susceptible to injuries. The significant risk factors for rugby related injuries have been summarized in Appendix I. This will be discussed in the following sections.

1.12.1 Anthropometry

Body mass index (BMI) is used to classify body fat and is calculated from weight (in kg) divided by the square of height (in m) (Keys *et al.*, 1972). BMI has been suggested to be a contributing factor to rugby-related injury (Quarrie *et al.*, 2001; Chalmers *et al.*, 2012). It has been suggested that those with BMI > 25 sustained more injuries (10.7/100 player games) than those with BMI < 20 (5.8/100 player-games) (Chalmers *et al.*, 2012). Furthermore, the injury incidence was higher for players with BMI of greater than 26.5 in comparison to that of < 23 (Quarrie *et al.*, 2001). It has also been reported that severe shoulder injuries was sustained in players with BMI > 30.9 (Headey *et al.*, 2007).

Regarding body weight, there is evidence that incidence of recurrent contact injury significantly increased in players with weight > 96.5 kg (hazard ratio [HR] = 2.6, 95% CI = 1.2-5.7) (Gabbett *et al.*, 2012b). Players with weight > 81 kg compared to those with < 74 kg sustained more injuries and missed a larger percentage of their season, 17% and 10% respectively (Quarrie *et al.*, 2001). Similarly, in schoolboy players, heavier players (> 77 kg) are at higher risk of injuries (adjusted HR = 1.3; 95% CI = 1.04-1.69) (Archbold *et al.*, 2015). Increased risk of injury for heavier player may be related to exposure, as larger players played longer duration in matches. It may also be due to a higher volume of collisions as the larger body produces higher force in contact events (Gabbett *et al.*, 2012b; Archbold *et al.*, 2015).

In terms of height, although the differences were not significant, the lowest rate of injury incidence was found in the tallest players (197–204 cm) at the professional level (Headey *et al.*, 2007). There was no association between height and risk of injury in amateur rugby players (Chalmers *et al.*, 2012).

1.12.2 Age

Many studies have identified age as a risk factor for injury; with the incidence and severity increases with increasing age. Players aged 25-29 years sustained almost two-fold injury risk compared with players aged less than 16 years (OR = 1.98; 95% CI = 1.09-3.60) (Lee *et al.*, 2001). It was also reported that the under 16 and under 17 (U16-U17) age group was injured significantly more than younger age group (U9-U10) (Haseler *et al.*, 2010). There is evidence that the proportion of recurrent injuries increased with age; from 8% in players U16 years old to 39% in players aged 30-34 years of age (Garraway & Macleod, 1995). With increasing age from U13 to 20 years the injury incidence of head, face and neck rose from 43.3 to 73.4/1000 player hours (McIntosh *et al.*, 2010a). The findings of a 26-year injury surveillance study at the US emergency departments showed that the age of injured men (23.3 ± 5.7 years) was older than women (21.2 ± 4.7 years) (Yard & Comstock, 2006). The evidence of an association between the injury incidence rate and age stated that risk of injury was higher for all the players older than 13-15 year of age (Chalmers *et al.*, 2012). An explanation was that mechanical degeneration connected with repeated load application result in reduction tissues stress tolerance capacity (cumulative load theory) (Kumar, 2001). In addition, this can also be explained by the increased size of older players and the greater intensity of which the match is played (Noakes & Du Plessis, 1996).

An investigation of professional rugby union players examined the influence of age on sustaining injury. There were no significant differences in injury incidence as a function of age. However, player < 21 years old were at higher risk of being absent due to injury (mean severity of 18 days) than the older players (mean severity of 14 days). One possible reason is that the physical characteristics of younger players have not developed sufficiently to tolerate the playing demands at this level. Furthermore, at the professional level, head injury was lower in older players (> 29 years). It has been suggested that players with greater experience are more efficient in escaping from dangerous situation (Brooks, 2004).

1.12.3 Gender

A similar injury incidence has been reported for both gender for amateur rugby union players, namely 16.9 and 17.1 per 1000 player-hour for males and females respectively (Kerr *et al.*, 2008). However, another study reported a significantly higher rate of injury for males compared to females in match (10.9 *vs*. 6.1/100 player games) (Bird *et al.*, 1998). The trend was similar for rugby-7s players that the injury incidence was 74.7 and 10.0/1000 playing hours for male and females respectively (RR= 7.5; 95% CI = 2.7-20.7) (Lopez *et al.*, 2012).

Regarding the type of injuries, female players sustained more sprain/strain (injury proportion ratio [IPR] = 1.39; 95% CI = 1.16-1.67), contusion (IPR = 1.48; 95% CI = 1.14-1.92). For male players, they sustained more laceration (IPR = 4.23; 95% CI = 2.87-6.22) and dislocation (IPR = 2.17; 95% CI = 1.51-3.13). A higher proportion of face injuries occurred in male players (IPR = 2.05; 95% CI = 1.54-2.72). The high injury incidence of laceration and face injuries may be a reflection of high frequency of foul play in the male game (Yard & Comstock, 2006) as foul play commonly affects head and face and leads to laceration (Bird *et al.*, 1998).

Female players had a higher proportion of knee injuries (IPR = 1.67; 95% CI = 1.36-2.06) (Yard & Comstock, 2006). For collegiate rugby players, the rate of ACL injury in female players was two times more than male players (Gwinn *et al.*, 2000). More recent injury data showed that the collegiate rugby female players were 5.3 times more at risk of ACL injury (IRR = 5.32; 95% CI = 1.33-30.5 (Peck *et al.*, 2013).

In addition, the rate of fracture was 2.5 times higher in male players. Male players were 2.2 and 6.6 times more likely to have AC joint injury and open wound injuries. Considering the rules of rugby play is the same for both genders, this difference can be due to differences in the performance of tackle, body size or different speed of the play (Peck *et al.*, 2013).

1.12.4 Previous injury

A history of previous injuries has been reported to be a risk factor for subsequent injuries (Lee *et al.*, 2001; Quarrie *et al.*, 2001; Bourne *et al.*, 2015). Players with a previous injury history had a higher injury incidence rate (109/1000 player hours) than those without previous injuries (50/1000 player hours) (Quarrie *et al.*, 2001). Also, players who sustained or were injured at the end of the past season were more likely to be injured in the following season (OR = 1.83, 95% CI = 1.34-2.50) (Lee *et al.*, 2001). More recently, players with a history of a hamstring injury, in the last 12 months, compared to those without such a history had 4.1 times greater risk of a recurrent hamstring injury (Bourne *et al.*, 2015).

There is evidence that recurrent injuries accounted for 12-19% of all injuries (Brooks *et al.*, 2005c; Williams *et al.*, 2013; Moore *et al.*, 2015; Whitehouse *et al.*, 2016). Players with a history of injury sustained a higher risk of subsequent injury. One of the possible reason may be caused by poor physical fitness and psychological well-being after injury (Lee *et al.*, 2001). This outcome emphasizes on the necessity to ensure players are fully rehabilitated before returning to play.

Of note, there is no evidence of an association between the risk of in-season injury and previous injury from the past 12 months (Chalmers *et al.*, 2012).

1.12.5 Physical fitness

As discussed in Section 1.4, rugby requires high levels of speed, agility, muscular strength of upper and lower limbs, aerobic capacity, balance and flexibility (Pook, 2012). It has been recommended that better-fitted players are less susceptive to fatigue, and might help to prevent injuries that are fatigue-related (Brooks *et al.*, 2005a). Previously, low levels of fitness have been identified as risk factors in amateur Australian football players (McManus & Cross, 2004). Another study identified that football players that underwent only a short pre-season preparation were more susceptible to injuries, particularly at the beginning of the season; because they may not be physically fit enough (Braham *et al.*, 2004). There is evidence to indicate the use of physical fitness qualities to predict injuries in other similar sports such as Australian rules football and rugby league (Gabbett & Domrow, 2005; Gabbett *et al.*, 2012b; Freckleton *et al.*, 2013). Deficit strength of hamstring muscle as assessed by single leg hamstring bridge (SLHB) test, have been identified as a predictor for injury in Australian rules football. However, in this study, the injury incidence rate was very small (5.5%), it is hard to determine whether this reduced SLHB score was an outcome from previous strain injury that has not been fully recovered, or whether the reduced SLHB was the risk factor (Freckleton *et al.*, 2013).

A study on semi-professional rugby league players with low VO_{2max} (OR = 6.2, 95% CI = 1.23-31.1) was associated with a greater risk of contact injuries. The slower players, as assessed by 10 m (OR = 10.3, 95% CI = 1.4-75.7) and 40 m (OR = 9.9, 95% CI = 1.3-75.6) speed test, were at higher risk of injury (Gabbett & Domrow, 2005). However, in professional rugby league players, the findings demonstrated that faster players assessed by 40 m speed test were at higher risk of injury (HR = 2.1; 95% CI = 1.0-4.2) (Gabbett *et al.*, 2012b). The difference between professional and semi-professional players may reflect the physical demands of competition, at least in relation to locomotor activity, that at the professional level is greater than semi-professional level (Gabbett *et al.*, 2012a). Further, it is possible that the defensive system in semi-professional level was less developed than professional competitions. As a consequence, the better developed defensive system, in professional players, lead to the greater number of defenders involved in tackle. Therefore the possible injury risk for faster players increases, as faster speed can generate greater impact force during contact (Gabbett *et al.*, 2012b). The aerobic performance, as assessed using multistage shuttle tests, had no influence on the incidence rate of injury in rugby union players (Quarrie *et al.*, 2001). Professional rugby league players with lower high-intensity intermittent running ability were at higher risk of contact injuries (HR = 2.9; 95% CI = 1.7-0.5) (Gabbett *et al.*, 2012b). It might be because early fatigue caused a decrease in tackling technique, consequently leading to an increase in incidence rate of tackle injuries in rugby league playing (Gabbett, 2008). Nonetheless, whether these results can be applied to rugby union is unclear. In addition, rugby league players with poor upper body strength, as measured by chin-up test, had a greater incidence rate of contact injury (HR = 2.2; 95% CI = 1.3-3.7) (Gabbett *et al.*, 2012b). In rugby union, physical fitness parameters have been used commonly to determine the physiological characteristics for players at different levels for determination of playing positions and for assessment of physical demands of the game (Nicholas, 1997; Duthie *et al.*, 2003; Roberts *et al.*, 2008; Darrall-Jones *et al.*, 2015). However, few studies have tested the relationship between physical fitness and injury risk in rugby union (Lee *et al.*, 2001; Quarrie *et al.*, 2001; Tee *et al.*, 2016). A study investigated the risk factors of injury for 258 professional players during a full competitive season indicated an assocation between upper body strength (as assessed by push-up test) and the proportion of the season missed. However, the pattern of association was not linear, making the interpretation difficult. Further, the faster players (< 3.76 s, as assessed by 30 m speed test) had a higher incidence rate of injury compared with the slower group (> 4.06 s) (RR = 1.51; 95% CI = 1.0-2.3) (Quarrie *et al.*, 2001). An explanation is that because of greater contact speeds and collision forces, faster players are at higher risk of injury (Quarrie & Hopkins, 2008). More recently, an investigation was conducted for professional South African rugby union that used functional movement screen (FMS) tests including in-line lunge (ILL), deep squat (DS), shoulder mobility, hurdle step, active straight leg raise (ASLR), push-up, rotary stability and trunk stability to find out if FMS tests can predict severe contact injuries. The results indicated that the FMS composite score (OR = 5.2; 95% CI = 2.0-14.0) and also different combinations of tests; ILL + DS (OR = 6.5; 95% CI = 0.8-54), ASLR + ILL (OR = 4.3; 95% CI = 0.9-21) and ILL + DS + ASLR (OR = 5.5; 95% CI = 1.1-27) were significant predictors for severe contact injuries (Tee *et al.*, 2016).

In summary, upper body and lower body strength, speed, intermittent running ability and composition score of FMS have been identified as potential risk factors for injuries. However, additional studies are needed to provide valuable insight into the function of different fitness elements upon injury risk in rugby union players.

1.13 EXTRINSIC RISK FACTORS FOR INJURIES IN RUGBY

1.13.1 Playing position

One of the injury risk factors in rugby union is playing position (Brooks & Kemp, 2011). There is evidence which identified that back position was significantly associated with higher risk of non-contact injury incidence in match (Brooks *et al.*, 2005a) while forward sustained significantly more recurrent injuries during training (Fuller *et al.*, 2013). Among all playing positions, hookers and fly-halves were reported to sustain the highest incidence of injury, 114 and 108/1000 player hours respectively. The most severe injuries were from the right locks and open side flankers, accounting to 27 and 22 missed days respectively at the professional level (Brooks *et al.*, 2005a). Also, the incidence of ruck/maul injuries was significantly higher for forwards while backs significantly sustained more tackled injuries (Brooks *et al.*, 2005a; Fuller *et al.*, 2007a). In another study that investigated junior rugby players observed that flankers, number eight, wings and hooker were at higher risk of injury, regardless of severity. There was also significant association between playing position and severity of injuries. The most severe injuries happened for lock, center and halfback positions during tackle (McManus & Cross, 2004). A study on community level players showed significant differences between forwards and backs. Backs sustained more thigh injuries that could be related to high-intensity running while more head and neck injuries were sustained in forwards due to more significant contact in the game (Roberts *et al.*, 2013). A study on professional level players demonstrated that backs significantly sustained more hamstring injuries during match than forwards (8.6 *vs*. 3/1000 player hours) (Brooks *et al.*, 2006) and forwards sustained significantly more ankle injuries than backs during training (0.37 *vs*. 0.19/1000 player hours) (Sankey *et al.,* 2008). The possible explanation for higher ankle injuries in forwards can be due to landing from height during the line out as 40% of ankle injuries was sustained during line out (Sankey *et al.*, 2008). The higher incidence of hamstring injuries can be related to faster speed and the greater distance covered backs compared with forwards (Brooks *et al.*, 2006).

Despite the evidence, there are some studies which documented no significant differences in the profile of injury and also in severity for different positions (Fuller *et al.*, 2010c; Brooks & Kemp, 2011; Whitehouse *et al.*, 2016). One probable explanation is that positions are usually grouped for statistical analysis which may cover-up any personal differences between particular positions (Cahill *et al.*, 2013).

Overall, the injury incidence between forwards or backs seems to be similar, but it should be considered that different position may sustain different type of injuries (Brooks & Kemp, 2011). Thus, injury prevention program should be specified based on the position of playing as well (Williams *et al.*, 2013). Despite anthropometrical differences, it is not uncommon to observe rugby players play in more than one role either in attack or the defensive phase. In this case, the function of playing position perhaps will be of no significance in injury incidence and severity (Calvisi *et al.*, 2016).

1.13.2 Time of the match

With considering the time during the game, some evidence shows that 46-60% of the injuries happened in the first half of the match (Bird *et al.*, 1998; McManus & Cross, 2004). Furthermore, it was reported that most hamstring injuries were sustained in the first match quarter, possibly suggesting that an adequate warm-up may be necessary (Roberts *et al.*, 2013). Other than that, the injury incidence in the first quarter of the match has been reported to be the lowest (Holtzhausen *et al.*, 2006).

In contrast, injuries occurred more often in the second half, either in the third quarter (Dallalana *et al.*, 2007; Williams *et al.*, 2013; Kaux *et al.*, 2015) or last quarter of the match (Brooks *et al.*, 2005a; Fuller *et al.*, 2007a). More specifically, knee injuries happened more frequently in the second half of the match especially in the last quarter (Dallalana *et al.*, 2007). In terms of severity, more severe injuries such as ACL injuries were observed for backs in the third quarter (Brooks *et al.*, 2005a). A majority of ankle injuries occurred during the second half, particularly, in last 20 minute of the game (Sankey *et al.*, 2008). Regarding shoulder injuries, with the match progresses, the rate of injuries increases (Headey *et al.*, 2007). These results signify that fatigue maybe an injury risk factor in the second half of the match compared to the first half (Brooks *et al.*, 2005a).

There are however studies which reported no differences between the incidences of injury as well as injury severity in the first half and the second half of the matches in professional players. It maybe perhaps professional players were not at an increased risk of injury when fatigued due to good physical fitness (Moore *et al.*, 2015).

1.13.3 Time of the season

The incidence of injury during the in-season match was significantly higher than that of reported for preseason match at the professional level (Brooks *et al.*, 2005a). One possible reason for lower incidence was probably due to the lower competitive nature of the matches, which were usually friendly games (Quarrie *et al.*, 2001; Brooks *et al.*, 2005a).

Pre-season training induced significantly higher injury rate (38% of all training injury) in comparison with other parts of the season (Holtzhausen *et al.*, 2006). It could be related to the lack of general conditioning, low fitness level and insufficient recovery from previous injury (McManus & Cross, 2004; Brooks *et al.*, 2005b; Holtzhausen *et al.*, 2006). Furthermore, it was found that there was a significant association between time of the season and severity of injury. Seventy-three percent of severe injuries happened in the first month of the season. A possible explanation reported being the addition of extra training sessions and practice games per week leading to inadequate recovery between sessions, and result in injury. With the progress of fitness into the season as well as techniques improved which lead to a decrease in injury (McManus & Cross, 2004).

1.13.4 Excessive training

Skill training and conditioning programs are used to develop the physical and technical demands of rugby. Several authors have studied the connection between training load and injury (Quarrie *et al.*, 2001; Brooks *et al.*, 2008; Viljoen *et al.*, 2009; Chalmers *et al.*, 2012). It was documented that participating in physical activity of 5-39 hours per week protected players from injury but participation > 39 hours of training per week increased the risk of injury (RR= 1.86) (Quarrie *et al.*, 2001). More recently similar result was presented in amateur players that training of over 40 hours physical lead to greater risk of severe injuries (IRR = 1.54, 95% CI = 1.1-2.2) (Chalmers *et al.*, 2012). A prospective cohort study in professional rugby union players, reported that the optimal training volume ranged from 6.1-9.1 hours per week. Training volume higher than 9.1 hours per week was not associated with higher rate of injury incidence but increased in severity of injuries (Brooks *et al.*, 2008). The training activities that attributed to greater risk of injury were ruck and maul, defense and fitness tests (Brooks *et al.*, 2008).

In rugby league players, a 11-16% decrease in pre-season training was associated with a 40-50% reduction in the incidence of injury (Gabbett, 2004). Specifically, an investigation for hamstring injury on professional rugby players identified that sustaining a severe hamstring injury (> 3 weeks absence) in the match was significantly higher when the volume of the previous week training was more than 12.5 hours (Brooks *et al*., 2006).

1.13.5 Playing experience

Player's experience has been known as a potential risk factor for rugby-related injuries (Quarrie *et al.*, 2001; Kerr *et al.*, 2008). An experienced player is expected to perform a technique properly which may protect him from injury. In contrast, poor technique can be a contributing factor to cause injury (Quarrie & Hopkins, 2008).

Players with 6-7 years playing experience had lower injury incidence than those with less than three years of playing experience (75 *vs*. 97/1000 player hours). However, injuries of experienced player tended to be severe (relative risk of 1.44 *vs*. 0.42) (Quarrie *et al.*, 2001). It has been reported that severe injuries were significantly lower in players with < 10 years of playing experience (OR = 0.22, 95% CI = 0.1-0.8)

(Gabbett & Domrow, 2005). The result of another study showed that the players with 1-3 years playing experience sustained 51% of all injuries compared to more experienced players (> 3 years) and those with less than one-year playing experience (Kerr *et al.*, 2008).

1.13.6 Level of play

The introduction of professionalism (in 1995) in rugby union paralleled with the increase of injuries in both professional and amateur players. Garraway *et al.* (2000) studied two seasons: 1993-94 and 1997-98 and found that the percentage of injured players approximately doubled (from 27% to 47%). There is a common belief that injury rate increases with increasing of age, level, and standard of the game (McIntosh *et al.*, 2010a; Palmer-Green *et al.*, 2013; Williams *et al.*, 2013). A study was found that injury incidence was higher for semi-professional players (21.7/1000 player hours) compared with amateur players (16.6/1000 player hours) (Roberts *et al.*, 2013). Also, a comparison between match injury incidence in youth academy and school players showed that the incidence of injury was higher in academy players than school level (47 *vs*. 35/1000 player hours) (Palmer-Green *et al.*, 2013). On one hand, players at higher level of playing are stronger and more physically fit because of better conditioning which could be protective for players (Olsen *et al.*, 2005; Brooks *et al.*, 2006). However, on the other hand, stronger players produce greater force during contact phases and are probably to be involved in more collision events thus they are much more vulnerable to injury (Palmer-Green *et al.*, 2013).

In a study over a 3-year period of rugby-7s players, slightly higher injury incidence was reported in amateur players than professional players (49.3 *vs*. 32.6/1000 player hours) (Ma *et al.*, 2016). It has been identified that the risk of tackle injury was significantly lower for younger players than professional players (OR = 0.25, 95% CI = 0.08-0.93). Younger players tended to use more passive tackle techniques in contrast to active techniques. (McIntosh *et al.*, 2010b). Also, the incidence of injury was reported to be higher in the club competition than during friendly competitions (98 *vs*. 67/1000 player hours) (Brooks *et al.*, 2005a). The higher rate of injury at higher levels of competition may be related greater power and greater body size of the players, greater distance covered by faster players, higher levels of competitions, longer season, greater ball-in-play (Williams *et al.*, 2013).

1.13.7 Ground surface

It seems that the condition of the ground, particularly surface hardness, is a major contributor to injuries (Lee & Garraway, 2000). The risk of playing on hard surface is 50% higher than firm ground (Chalmers *et al.*, 2012). Regarding artificial turf and grass, two studies considered the relationship between artificial turf and risk of injury in rugby union players (Fuller *et al.*, 2010b; Williams *et al.*, 2016).

Fuller *et al.* (2010b) found that although the incidence of ACL injury was four times more on artificial turf than grass, the difference was not significant (rate ratio = 3.82). Also, in terms of severity and the overall incidence of injuries, there was not a significant difference between training on artificial turf and grass.

The investigation on time loss and abrasion injury risk, and muscle soreness showed no significant difference in the overall injury risk between two surfaces. Abrasion was more prevalent in artificial surface than grass one but did not result in time lost (rate ratio = 7.92). Muscle soreness was higher over the four days after a match on artificial turf than grass, but the effect size was small (0.3-0.4). The playing surface may alter the nature of the game included ball-in-play time, the speed of running, and fatigue levels (Williams *et al.*, 2016).

1.13.8 Equipment

Padded equipment for the head, shoulder, and chest, and mouth guards have been used to reduce the risk of injury (Brooks & Kemp, 2008). There is evidence that the incidence of shoulder injuries sustained by players using shoulder pads was similar to those who did not use shoulder pads. There was also no difference in terms of missed days of play (Headey *et al.*, 2007). A mouth guard is used to decrease dental injury, and it was believed that mouth guard reduces the risk of concussion injury but later it was reported that it is not an efficient equipment to decrease concussion injury (McCrory, 2001; Daneshvar *et al.*, 2011). Research to date indicates that protective equipment used in rugby union has insufficient effectiveness in preventing injury (Marshall *et al.*, 2005). Even, there is evidence that the risk of injury increased 23% for headgear users compared with non-headgear-users (injury rate ratio = 1.23) (Chalmers *et al.*, 2012).

1.14 SUMMARY

Playing at different levels and different formats of rugby union could contribute to a variation in injury profile. Recognition of injuries and factors is a necessity in order to develop injury reduction strategies. The contribution of different components of physical fitness as an injury risk for rugby union players is not well known. Therefore, there is a need to fill the gap in this arena of knowledge.

1.15 AIMS OF THE INVESTIGATION

The overall aim of this prospective study had two folds:

1. To investigate the injury incidence of rugby players in Hong Kong at different levels (amateur, semi-professional) and different formats (7s, 15s) of play
2. To identify risk factors that predict severe rugby-related injuries for different levels and formats of play.

CHAPTER 2

GENERAL METHODOLOGY

2.1 INTRODUCTION

This chapter presents the study design, the procedures, the measurement tools and the data analysis of the study.

2.2 STUDY DESIGN

This prospective cohort study aims to determine the injury incidence, risk factors (gender, height, weight, playing experience, previous injury, speed, agility, muscular strength of upper and lower limbs, aerobic capacity, balance and flexibility), associated with the injury, and to investigate if preseason physical tests can predict injury for rugby players. The investigation included two studies; one study was conducted on tertiary rugby-7s players in season 2014-15 and the second study was conducted throughout rugby-15s season in 2015-16 (September to March, 28 weeks). The first study focused on amateur players while the second study was conducted on players at amateur and semi-professional level. Prior to the commencement of formal training, baseline information included demographics data, players' characteristics (playing experience, playing position, previous injury and fitness level) was gathered, the players were followed throughout the season for any rugby-related injuries.

2.3 ETHICS STATEMENT

All players were informed of the study procedures and completed informed consent in writing (Appendix II). The Human Subjects Ethics Sub-Committee of Hong Kong Polytechnic University approved this study (Reference: HSEARS20140828002. (Appendix III).

2.4 PARTICIPANTS

The rugby players were recruited at the beginning of a rugby season. In season 2014-15, the participants were amateur rugby-7s players recruited from three universities from Hong Kong. In season 2015-16, the rugby-15s players were recrutied from Tigers Rugby Football Club. The club has both amateur and semi-professional players. Inclusion criteria were players that participated in all regular training and competitions. Participants were excluded if they had a health problem that prevented them from participating in the fitness testing.

2.5 PROCEDURE

Before the commencement of formal training, players were asked to complete a questionnaire and complete an array of physical fitness tests. In our first study for rugby-7s players, ten physical fitness tests were used. After the completion of the first study, we felt that the ten tests could not adequately address all the domains of the physical fitness required. As such, an additional 8 tests were added for the second study on rugby-15s players. All players were followed throughout the season (28 weeks) for injury surveillance.

A questionnaire was provided to collect personal characteristic of the players at the start of the season. (Appendix IV) The information included: gender, age, height, weight, playing experience, medical history and previous injury. The details of previous injury include date of injury, training or match injury, type and location of injury, injury mechanism (contact/non-contact), also specific causes of injury in terms of mechanism of injury that was due to rugby skills (tackled, tackling, ruck, maul, scrum) or general sports activity (running, jumping, twisting or turning), the rate of recovery and return to play after the injury.

The preseason fitness tests were performed within a period of four weeks before the commencement of formal training. All fitness tests were measured by trained assessors that underwent three training sessions to ensure the standardized performance of the tests. All testing sessions were conducted on artificial turf pitches; the participants were given a verbal and physical demonstration for each test. On the test day, after a structured warm-up, the players rotated between different testing stations for testing. The sequence of the tests and rest periods between tests were developed in such a way that the previous test would not affect the performance on the next test and fatigue was controlled.

Rugby requires high levels of muscular strength of upper and lower limbs, stability, balance, flexibility, speed, agility and aerobic capacity, (Gamble, 2004; Pook, 2012). Thus, the high reliable physical fitness tests were selected according to these requirements using previous studies (Carlson *et al.*, 1994; Nicholas, 1997; Maria van Gent & Spamer, 2005; Durandt *et al.*, 2006; Jarvis *et al.*, 2009; Fernández *et al.*, 2011; Hene *et al.*, 2011; Barr *et al.*, 2013; Darrall-Jones *et al.*, 2015; Chiwaridzo *et al.*, 2016). The overall methodology used in each test was described in the following sections.

STRENGTH

2.5.1 Isometric mid-thigh pull test

This test is a reliable tool (Intraclass correlation coefficient [ICC] = 0.95-1.00) for measuring back strength and had been used for rugby players (West *et al.*, 2011;

McMaster *et al.*, 2014; Darrall-Jones *et al.*, 2015). The player stood on the wooden frame and pulled on a handlebar attached by a metal chain to a load cell (Figure 2. 1). The height of the handlebar is adjusted such that it crosses the midpoint of the thighs, between the hip and knee joints. The player was instructed to pull the bar upward rapidly with maximal effort keeping the back straight, knees and hips flexed and head up. During this movement, only the back muscles work and the apparatus set into the chain displays the force in kg. The trial counted in with the instructions “3, 2, 1, GO!”

2.5.2 Vertical jump test

Vertical jump test has frequently been used to assess the leg power in rugby players (Quarrie *et al.*, 2001; Duthie *et al.*, 2003; Edwards *et al.*, 2008). This method is simple to use, needing a wall and chalk powder to make marks with the fingers. An excellent reliability of 0.93 was reported for this test (Johnson & Nelson, 1979). The player positioned him/herself with the dominant side towards the wall with feet together (Figure 2.2). The end of his/her fingertips of dominant hand was chalked and reached up with the hand closest to the wall (M1). The player then stood away from the wall in a static position using both legs and arms to help in projecting the body upwards then he jumped as much as possible and marked the wall with the chalk on the fingers (M2). The highest point marked by the middle finger recorded. The best score was the greatest difference in distance between the two marks (M1, M2). The best of three trials was recorded (Shaji & Isha, 2009).

Figure 2. 1 Isometric mid-thigh pull test

Figure 2.2 Vertical jump test

2.5.3 Single leg hamstring bridge test (SLHB)

The SLHB has been suggested as a reliable test to assess the strength of hamstring muscle (inter-tester ICC = 0.89-0.91, intra-tester ICC = 0.77-0.89) (Hallet, 2010). A box with a height of 60 cm was used for testing all participants. The player was asked to put one heel on the box and lie supine on the ground. The tested leg was placed in about 20° knee flexion. The player was asked to cross arms over the chest and lift the buttocks off the ground. The aim of the test was to perform as many repetitions as possible until fatigue (Figure 2.3). To ensure that the correct technique was done, consistent feedback was provided throughout the procedure of the test. It was important that at each trial, the player's buttock touched the ground, and then extended the hip to 0° without rest between each repetition. The non-working leg was required to be held stationary in a vertical position to ensure that it would not assist the movement. One warning was given for the first fault in movement, and the test was stopped at the next error in technique (Freckleton *et al.*, 2013).

2.5.4 Adductor squeeze test

In order to assess hip adductor muscle strength, the adductor squeeze test was adopted. This test has good intra-rater and inter-rater reliability (ICC) of 0.94 and 0.84 respectively (Malliaras *et al.*, 2009). In the context of rugby, this test was used to establish normative data for adductor muscle strength (Hodgson *et al.*, 2015). The player was required to perform maximal squeezes in 45° degrees of hip flexion while lying in supine (Figure 2.4). This angle was determined as the optimal position that had

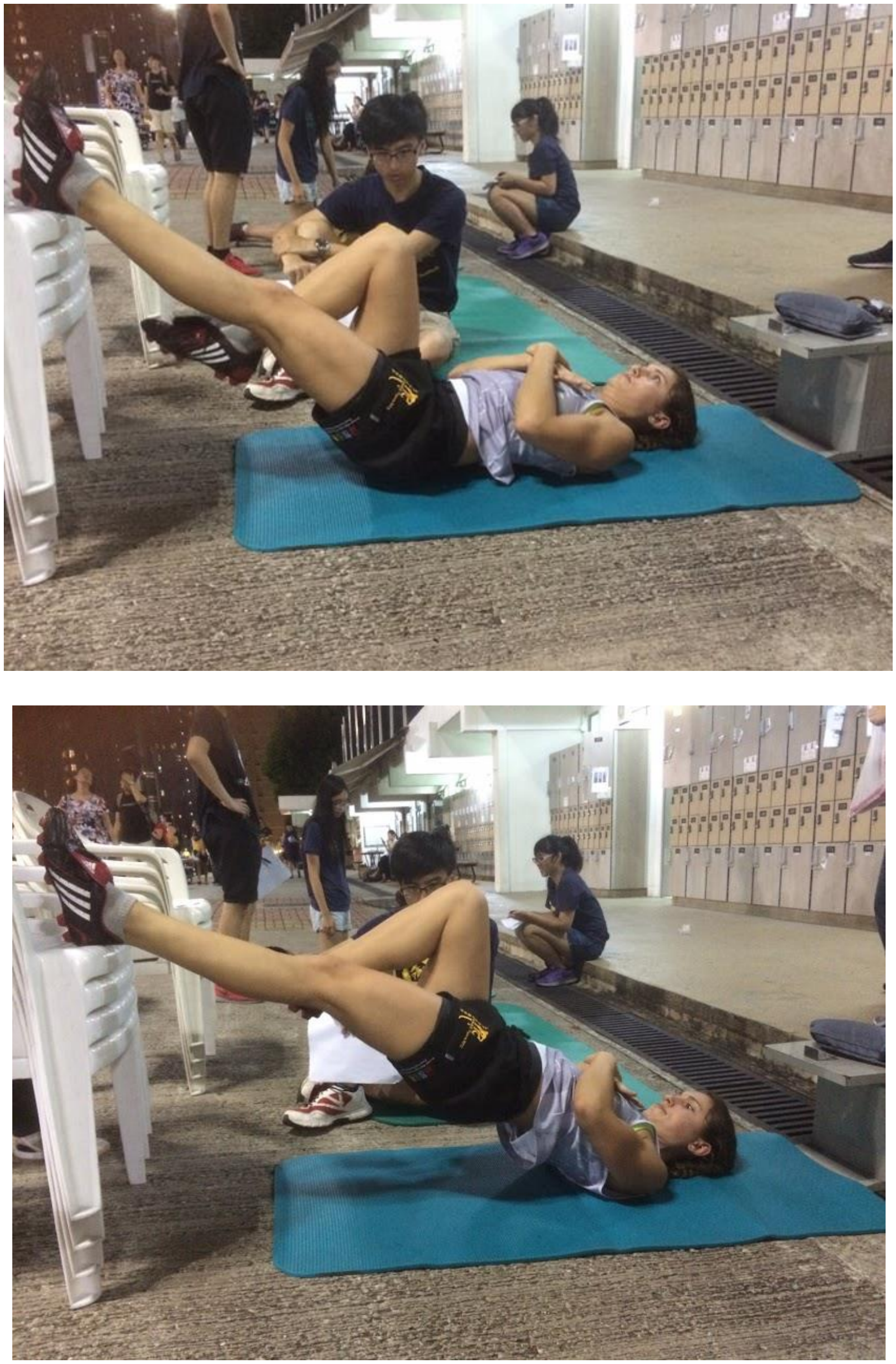

Figure 2.3 Single leg hamstring bridge test

Figure 2.4 Adductor squeeze test

minimum standard error of measuring (Delahunt *et al.*, 2011). The squeeze test was evaluated using a sphygmomanometer pre-inflated to 20 mmHg. The player was instructed to press as hard as possible on the cuff of the sphygmomanometer positioned between the knees as hard as he could and keep the contraction for 2 to 3 second. From three trials, the highest pressure value shown on sphygmomanometer dial, to the nearest 5 mmHg, was recorded (Malliaras *et al.*, 2009).

2.5.5 Push-up test

The strength and endurance of upper body in rugby union players was evaulated with this test (Carlson *et al.*, 1994; Quarrie *et al.*, 2001; Hene *et al.*, 2011). The reliability of the test was reported to be high (ICC = 0.88-0.94) (Baumgartner *et al.*, 2002; Gabbett *et al.*, 2008). The player was asked to lie on the ground, to place his/her hands by the shoulders with straight arms (Figure 2.5). The body was lowered until the elbows reached 90°, followed by a return to the starting position with arms fully extended. The push-up action was continuous without rest until the player was unable to continue. The number of correctly completed push-ups was counted and recorded.

2.5.6 Neck flexor muscle endurance test

The neck flexor muscle endurance test was used to determine the relative strength of the stabilizer of the deep neck flexors. Inter-rater reliability for this test has been reported to be moderate to good (ICC= 0.67-0.88) and for intra-rater reliability was good to excellent (ICC= 0.82-0.93) (Edmondston *et al.*, 2008; Juul *et al.*, 2013; Painkra *et al.*, 2014). The player was asked to lie in supine position (Figure 2.6) and

Figure 2.5 Push-up test

Figure 2.6 Neck flexor muscle endurance test

retract his/her chin maximally, lifting the head approximately 2.5 cm off the ground and keeping the chin retracted to the chest and running an isometric hold of the position until fatigue. Time was recorded to the nearest second using a stopwatch.

2.5.7 Basic plank test

The core muscle strength and stability can be evaluated with basic plank test (McGill *et al.*, 2012). Reliability (ICC) for the plank test has been reported to 0.97 (95% CI = 0.94-0.99) (Tong *et al.*, 2014). The player lied in prone with back and legs was held in a straight line (Figure 2.7). The test ended when the player could not hold the straight position. The time was recorded to the nearest second

2.5.8 Side plank test

This test was used to assess the strength of core and lateral muscles (McGill *et al.*, 1999; Leetun *et al.*, 2004; McGill *et al.*, 2012). Excellent reliability of 0.99 was reported for both sides of this test (McGill *et al.*, 1999).. The test began when the player raised the body off the floor with their feet and elbow (bent at 90°) on the ground (Figure 2.8). The test ended when the player could no longer hold the mentioned position. The time was recorded to the nearest second.

STABILITY

2.5.9 Single leg hop test

This test was used for measures of knee function and stability (Fitzgerald *et al.*, 2001; Reid *et al.*, 2007; Wikstrom *et al.*, 2009). The test-retest reliability of this test was

Figure 2.7 Basic plank test

Figure 2.8 Side plank test

good, ICC ranged between 0.76-0.96 (Fleiss, 1986; Munro & Herrington, 2011). The player was instructed to stand in single leg and then hop forward as far as possible (Figure 2.9). The distance was measured for three trials for both legs. The best record was recorded in centimeter.

BALANCE

2.5.10 Y balance test

Y balance test is an variation of the star excursion balance test. This test measures dynamic balance with the anterior, posterolateral (PL), and posteromedial (PM) as the three reaching directions (Kinzey & Armstrong, 1998). Intra-tester reliability (ICC) in ranged from 0.84 to 0.87 for all the directions and test–retest reliability was 0.89 to 0.93 (Plisky *et al.*, 2006). The limb length was measured from the anterior superior iliac spine to the lateral malleolus with a tape measure while the player lied supine (Plisky *et al.*, 2006). The evaluation of three directions was carried out using three tape measures affixed to the floor where the tape measures meet at zero points in the center. One tape measure was orientated straight anterior to the apex, and the other two were aligned at 135° to this in the PM and PL directions. The player was instructed to keep the tested leg in foot flat on the floor with hands on the hips while reaching the opposite limb as far as possible along each of the tape measures (Figure 2.10). A slight touch on the ground with the tested leg and returning to a double-limb stance was required to complete the test. If these criteria were not met, the trial was discarded. The point of maximum reach distances was recorded for all directions (Fitzgerald *et al.*, 2010; Coughlan *et al.*, 2014b). The reach distance was normalized to limb length to

Figure 2.9 Single leg hop test

.

Figure 2.10 Y balance test

allow comparisons between players (Gribble & Hertel, 2003). A composite reach distance was calculated by summation of the normalized reach distance in three directions.

FLEXIBILITY

2.5.11 Sit and reach test

This test is used to measure hamstring flexibility and has been used in rugby players (Higgins *et al.*, 2013). The acceptable reproducibility measures for sit and reach test has been shown with ICC of 0.92 (Ayala *et al.*, 2012). The player sat on the floor with leg and feet kept straight against a sit and reach box. With the arms extended forward and one hand on top of the other, the player bent forward without bending their knees as far as possible and pushed the marker on the top panel of the standard sit and reach box (Figure 2.11). The measurement was recorded to the nearest centimeter. The best score of the three trials was used in the data analysis.

2.5.12 Thomas test

Thomas test was used to assess hip flexor tightness. The intraclass correlation coefficient values have been reported using goniometer, with inter-rater and intra-rater reliability of 0.60 and 0.52, respectively (Peeler & Anderson, 2007). The player lied in supine with the legs out straight on the floor while the excessive lordosis was checked by the examiner. The player lifted one hip while holding the flexed hip against the chest. If there was no flexion contracture, the hip being tested (the straight leg) would remain on the floor. If hip flexor contracture was present, the player's leg would be

.

Figure 2.11 Sit and reach test

lifted off the floor. The angle was measured by a goniometer (Magee, 2014) (Figure 2.12).

2.5.13 Hip internal rotation test

This test was used to assess passive hip internal rotation range of motion. Excellent inter-rater reliability and intra-rater reliability was reported with ICC 0.79 and ICC 0.96, respectively (Prather *et al.*, 2010). The player was asked to lie down in prone while the knee flexed to 90° and while keeping the knees together and allowing the feet to fall outward (Figure 2.13). To find out if the player had relaxed at the end of the movement, the examiner exerted soft overpressure. The angle between the vertical and the lateral border of the lower leg was measured by using inclinometer (Burns *et al.*, 2011).

2.5.14 Bent knee fall out

Bent knee fall out test is a reliable tool to measure changes in hip flexibility. The Intra-rater and inter-rater reliability (ICC) has been reported to range between 0.71-0.90 (Paul *et al.*, 2014). The player lied in supine with their knees flexed to 90°, while keeping the feet together and allowing the knees to fall out (Figure 2.14). The player was asked to relax and the examiner ensures maximal range of motion by adding overpressure on the knee. The distance between the head of the fibula and the plinth was measured and recorded in centimeter (Malliaras *et al.*, 2009).

Figure 2.12 Thomas test

Figure 2.13 Hip internal rotation test

Figure 2.14 Bent knee fall out test

2.5.15 Shoulder internal and external rotation tests

These tests were used to measure shoulder range of motion. The values of internal rotation and external rotation are indicative of posterior and anterior capsular tighness (Lin & Yang, 2006). The intra-tester reliability (ICC) for internal and external rotation of shoulder by using goniometer, ranged between 0.94-0.99 and the inter-tester reliability (ICC) ranged between 0.82-0.92 (Mullaney *et al.*, 2010). The player was tested in supine at 90° of glenohumeral joint abduction and 90° elbow flexion while the shoulder was positioned in the scapular plane. The arm was passively moved to the end range of internal (Figure 2.15) and external (Figure 2.16) rotation with the goniometer. The center of goniometer was positioned over the olecranon process while the stationary arm of the goniometer was in a vertical position with the moving arm aligned along the lateral aspect of the ulna (Ellenbecker *et al.*, 1996; Wilk *et al.*, 2009). The angle was recorded in degree. The total shoulder rotation passive range of motion was obtained by totaling the measures of maximum internal and external rotation range of motion (Wilk *et al.*, 2002).

2.5.16 Ankle dorsiflexion lunge test

Ankle dorsiflexion range of motion is assessed by this test. The inter-rater reliability (ICC) was reported to be high, ranging between 0.96-0.99 and intra-rater reliability was reported to range between 0.97-0.98 (Bennell *et al.*, 1998; Dennis *et al.*, 2008). The player was instructed to place the test foot against the wall while the heel and the big toe aligned on a tape measure (Figure 2.17). Then he/she was asked to lunge

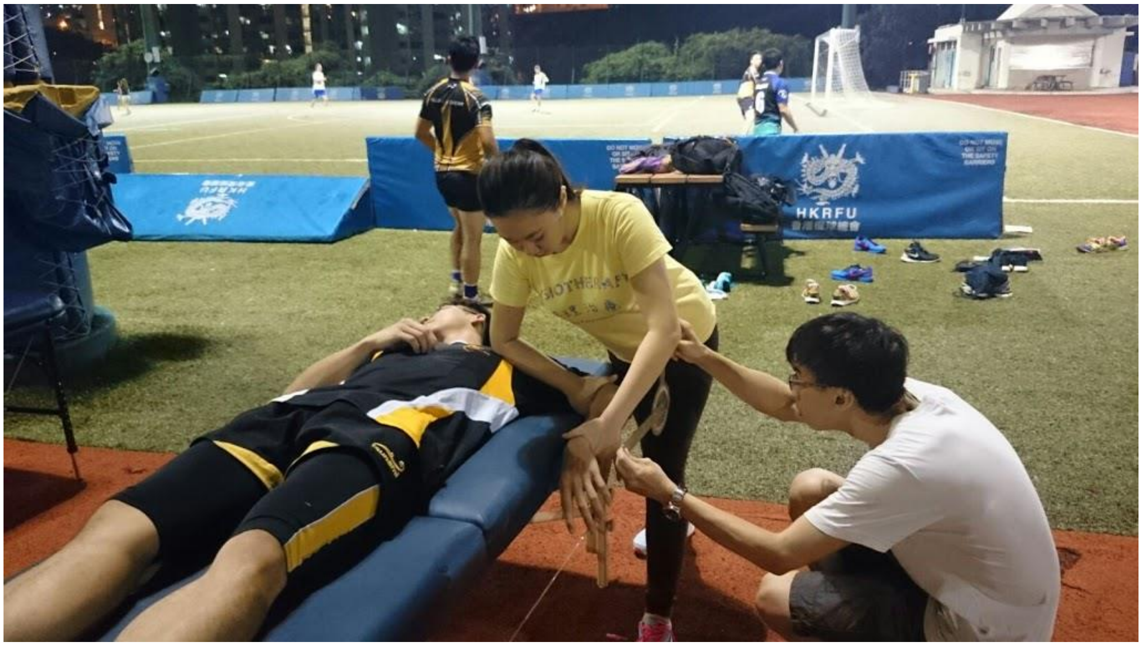

Figure 2.15 Shoulder internal rotation test

Figure 2.16 Shoulder external rotation test

Figure 2.17 Ankle dorsiflexion lunge test

forward so that the knee touched the wall while keeping the heel on the floor. The maximum distance from the big toe to the wall was recorded in centimeter.

SPEED

2.5.17 40 m sprint test

It has been shown that highly trained rugby players reach their maximal velocity between 30 and 40 m (Barr *et al.*, 2013) therefore this test is used to assess maximal velocity sprinting ability. The reliability of the test was reported to be high (ICC = 0.91-0.92) (Glaister *et al.*, 2009). The test involves running a single maximum sprint over 40 meters. The player started from a stationary position, with one foot in front of the other (Figure 2.18). With the command “GO”, the player sprinted 40 meters as fast as possible. As his/her chest passed through the finish line, the time was recorded to the nearest second.

AGILITY

2.5.18 Illinois agility test

The Illinois agility test was used to assess the ability to accelerate, decelerate, change in directions, and run at different angles (Homoud, 2015). The reliability of the test was reported to be high (ICC = 0.96) (Hachana *et al.*, 2013). In rugby union, this test was used to assess the differences between playing positions (Jarvis *et al.*, 2009). The distance of the area was 10 m x 5m (length x width). Four cones marked the start, end, and turning points. Another four cones were arranged in the center with an equal distance of 3.3 m (Figure 2.19). The player lied in prone with his/her head facing the

Figure 2.18 40 m sprint test

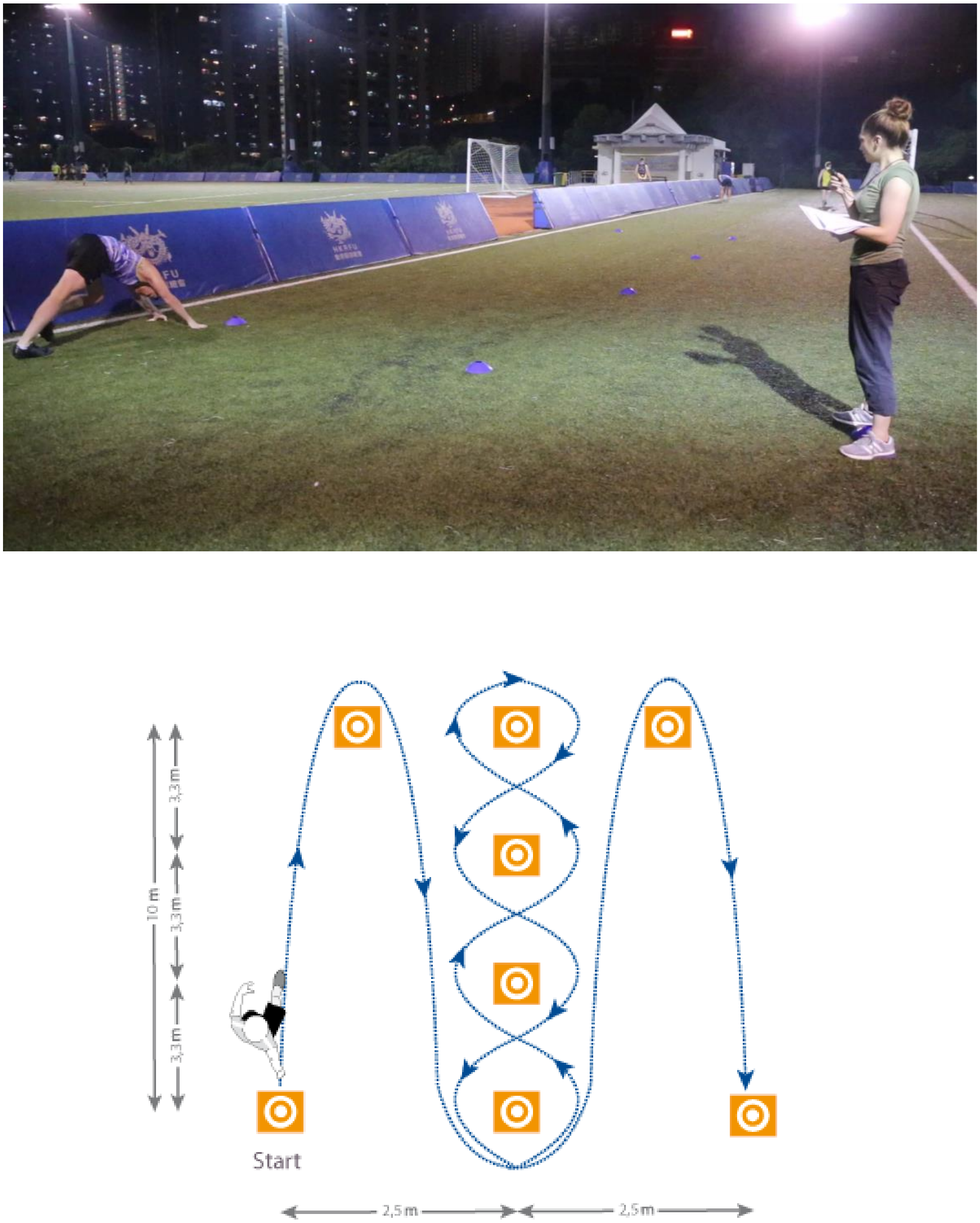

Figure 2.19 Illinois agility test

start line. On the “GO” command, the player got up as fast as possible while trying to avoid any touch to run through in the directions indicated. The time was recorded to the nearest second as he/she passed the finish line (Dawes & Roozen, 2012).

AEROBIC CAPACITY

2.5.19 Yo-yo intermittent recovery test (level 1)

The yo-yo intermittent recovery test has been recognized as a reliable test to estimate maximal aerobic capacity (ICC = 0.98) (Atkins, 2006; Veale *et al.*, 2010; Deprez *et al.*, 2014; Darrall-Jones *et al.*, 2015). The test followed the adopted guidelines (Bangsbo *et al.*, 2008) The test consists of 2 × 20 m shuttle run at increasing speeds, interspersed with a 10-second period of active recovery of 2 × 5 m of jogging (controlled by audio signals played from a CD player) (Figure 2.20). When the player was not able to reach the finish line in time twice, the total distance covered was represented the final result. The maximum aerobic capacity was determined by the formula:

VO_{2max} (ml.kg^{-1}.min^{-1}) = distance (m) × 0.0084 + 36.4.

2.6 TRAINING AND MATCH EXPOSURE

Exposure is measured as the total amount of time the players were exposed to the possibility of injury in training or competition prior to injury (Kennedy *et al.*, 2012). Over the 28-week period, rugby training and competition volume for each player were collected. Practice exposure time was determined by totaling the amount of team practice time that individual athletes participated in before the occurrence of their first

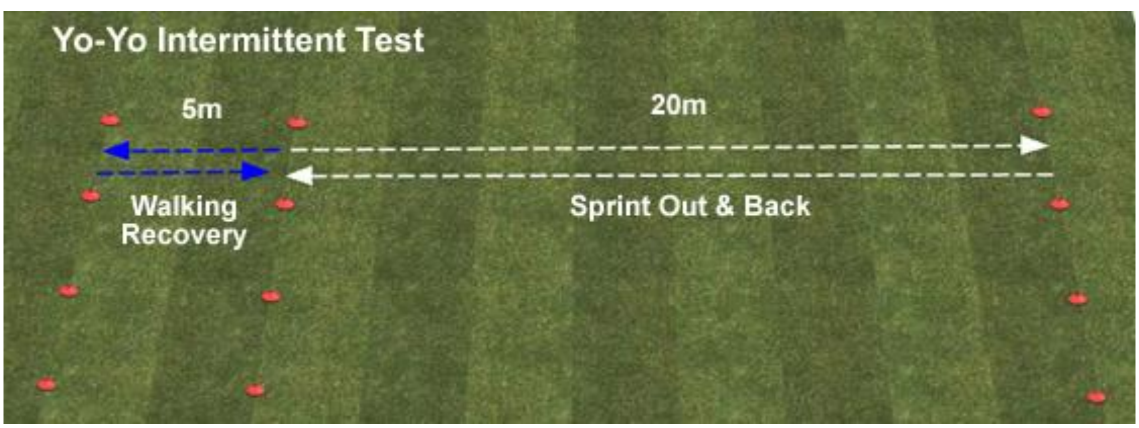

Figure 2.20 Yo-yo intermittent recovery test (level 1)

injury. Match exposure was derived from their weekly team game squad list. The game exposure time was calculated by multiplying the total number of matches by the duration of each match per player.

2.7 INJURY REPORTING

For the purpose of this study, rugby-related injury is defined as "any physical complaint sustained during a match or training session that prevented the subject from taking a full part in all training or match for 1 day or more following the day of injury, irrespective of whether match or training sessions were actually scheduled" (Fuller *et al.*, 2007c). In the case of an injury, the player was followed up to collect injury information using a standardized injury report form (Fuller *et al.*, 2007c). (Appendix V)

The time in the match that injury occurred was recorded in the first quarter, second quarter, third quarter, fourth quarter or if it happened in the warm up or cool down phase. Time for training was indicated as the first or second half of the training session. The position of play, location, side of injury and injury type were also recorded. Details related to the mechanism of injury, whether it was contact or non-contact, type of contact or non-contact injuries and also if the injury was recurrent or new were documented. Details on the injuries were determined by the on-filed physiotherapists using the Orchard Sports Injury Classification System (OSICS) (Rae & Orchard, 2007). The injured players were followed up to monitor their process of treatment and number of days off from rugby activity.

Recurrence is defined as an injury of the same type and at the same site and which happens after a player's return to full participation from the injury (Fuller *et al.*, 2007c). The injury severity was represented using the number of days lost from training or match as follows: slight (0-1 d), minimal (2-3 d), mild (4-7 d), moderate (8-28 d), severe (> 28 d) (Fuller *et al.*, 2007c). Subsequently, the injury rate was calculated by the number of injuries/1000 player hours of training or match exposure.

2.8 INJURY INCIDENCE

Injury incidence was expressed as number of injuries per 1000 player hours of exposure (Fuller *et al.*, 2008). This is calculated by the total number of injuries over the study period divided by the exposure × 1000.

2.9 STATISTICAL ANALYSIS

Data was analyzed using the software package IBM SPSS Statistics for Windows, Version 20.0 (2011, IBM Corp, Armonk, NY). Descriptive data consisted of means and standard deviations (mean ± SD). Chi-square test (χ^2) or independent t-test was used. Chi square test was used to examine if there was any difference in the severe injury occurrence between position of play (backs/forwards); and t test was used to examine if there was any difference between in the number of missed days between backs and forwards. Incidences of injuries and proportions were compared by calculating z values. To determine significant predictors for the hazards of injury, Cox regression analysis was used. Time to the first severe injury was dependent variable even for players with multiple injuries (ranging from mild to moderate injuries). The independent variables included previous injury, gender, age, playing experience, BMI, weight, height and fitness tests. Potential predictor variables for injury were selected with Spearman's rho analysis. To control multicollinearity, the significant related independent variables were input into different Cox regression models. Variables with significance level $p < 0.10$ were included in the regression analysis using backward stepwise selection to develop a multivariate model. Hazard was defined as "the probability of being injured at a given point in time, having remained uninjured up until the point" (Hopkins *et al.*, 2007). Hazard ratios were reported with 95% CI. Recurring injuries were not considered in the survival curves. Kaplan-Meier curves were used to estimate the proportion of players who survived from injury during the season.

CHAPTER 3

INCIDENCE AND RISK FACTORS OF SEVERE INJURIES FOR UNIVERSITY RUGBY-7S PLAYERS

3.1 INTRODUCTION

The popularity of rugby has increased tremendously in the past decade, both locally and internationally. This is due to players' attraction to the rugby-7s game and the inclusion of the sport in the Rio Olympics 2016. The global participation in rugby increased from 2.6 million in 2007 to 7.7 million in 2015, and it is predicted to reach 11 million by 2020 (World Rugby, 2016). There is an effort to boost rugby participation in schools and universities. In the U.S., rugby is considered as an emerging team sport in universities (NCAA, 2016). Despite increased participation in rugby at the university level, there is limited research on health and safety aspects for university students who play rugby.

Rugby-7s differs from the 15-a-side rugby (rugby-15s) in the number of players (7 *vs.* 15) and the duration of the match (7- *vs*. 40-min halves). The physical demands in the Sevens game are greater than 15-a side, with many high-intensity sprints, open-field tackles, rapid acceleration, deceleration and change of direction (Ross *et al.*, 2014). The fast pace of the game can result in numerous physical collisions and tackles, and the athletes are vulnerable to serious injuries. The incidence and severity of injuries were reported to be higher in rugby-7s than rugby-15s. For instance, the injury incidence sustained by elite, professional players during match play in rugby-7s was 106.2 per 1000 player-hours and 84 per 1000 player-hours in rugby-15s (Fuller *et al.*, 2010c). For concussions, the incidence and severity sustained were greater in rugby-7s players (Fuller *et al.*, 2015).

Prospective injury surveillance is much needed to evaluate risk factors and to help develop injury prevention strategies. Numerous risk factors have been examined through epidemiological studies, including previous injury, training volume, body mass index, ligament laxity, cigarette smoking status, experience, age, weather and ground conditions, level of play, length of season, and foul play (Quarrie *et al.*, 2001; Brooks & Kemp, 2011; Chalmers *et al.*, 2012). Other research indicates that physical fitness can predict injuries: players with lower upper body strength, lower maximal aerobic capacity and high-intensity intermittent running ability had a greater risk of injury (Gabbett & Domrow, 2005; Gabbett *et al.*, 2012b). However, these studies were conducted for club and elite-level players. There are limited injury surveillance studies for amateur players. Furthermore, the contribution of different components of physical fitness to injury risk for players, specifically in the Sevens version, is not well known.

In a study on amateur rugby players, a considerable proportion of injuries (40%) sustained were severe, resulting in at least five missed training/games. In addition to the loss of training, the athletes lost study time and work and also incurred medical costs (Gabbett, 2001). This clearly points to the need to assess the risk of severe injuries associated with amateur athletes who play rugby-7s, necessary for developing effective injury prevention strategies. Therefore, this study was undertaken (i) to determine the incidence of severe injuries (absence from rugby for > 28 d) sustained; and (ii) to identify risk factors for injury in amateur rugby-7s players at the university level.

3.2 METHODOLOGY

The study was conducted over one rugby season, from September 2014 to March 2015. A total of 104 rugby players (90M : 14F) aged 20.6 ± 1.9 years (mean ± SD) prospectively were followed during the rugby season. Based on the general methodology presented in Chapter 3, the players underwent the physical testing before the start of formal rugby training. Each player provided information regarding gender, age, height, weight, playing experience, medical history, and history of the previous injury. Ten tests were used to assess different components of physical function included:

1. Muscle strength and power: Push-up test to assess the strength of the upper body muscles (Gabbett, 2008), isometric mid-thigh pull test to assess back strength (Darrall-Jones *et al.*, 2015), vertical jump test to assess the leg power (Shaji & Isha, 2009), single leg bridge test to assess hamstring strength (Freckleton *et al.*, 2013).
2. Balance: Y balance test to assess dynamic balance (Plisky *et al.*, 2006).
3. Flexibility: Sit and reach to assess combined lower back and hamstring muscle flexibility (Ayala *et al.*, 2012), Thomas test to assess the flexibility of the hip flexors (Magee, 2014).
4. Speed and agility: 40 m speed test to assess the acceleration and speed (Glaister *et al.*, 2009), Illinois test to assess speed and agility (Dawes & Roozen, 2012).
5. Aerobic capacity: Yo-yo intermittent recovery test to assess maximal aerobic capacity (Bangsbo *et al.*, 2008).

During the season, any player that sustained an injury either in matches or during training was contacted weekly by the investigator. The player was followed up within 24 hours of the injury by physiotherapist. Specific details of the injury were collected using OSICS. The associated details related to the injury occurrence were provided using a standard report form. The details of report form and statistical method employed in this project has been presented in Chapter 3 (General Methodology).

3.3 RESULTS

3.3.1 Characteristics of university players

Data were collected from a cohort of 104 university rugby players (90M : 14F) with a mean age of 20.7 ± 1.9 years. The average playing experience was 21.0 ± 26.0 months (range 0 to 144 months), with 28 players who were completely new to the sport. All recruited players took part in regular training and competition with an average of 43.5 ± 26.0 training hours and 2.6 ± 1.6 match hours. The total training hour was 4525.5 ± 26.0 hours and match hour was 270.0 ± 1.6 hours competitions over the 28-week period (Table 3.1).

3.3.2 Injury history of university players

Injury history of the previous season (i.e. 2013-14) were acquired. Thirty-eight players (36.5% of all players) had at least an injury history in the past 12 months with sixteen players experienced more than one injury. Knee (21%), shoulder (13%) and ankle (11%) were the most common site of injuries. The most common type of injuries included ligament tear/sprain (21%) and tendon injury (14.5%). The majority of ligament injuries happened to the knee (77%), and tendon injuries commonly occurred to the shoulder (33%). Fracture injuries related to nose, finger, wrist, clavicle, ankle and foot as well as the ligament tears of finger and knee anterior cruciate ligament were the most severe reported injuries. Some other noticeable injuries were concussion lower

Table 3.1 Descriptive variables for university players (n = 104)

Descriptive variables	Males	Females
n	90	14
Age (years)	20.73 ± 2.06	20.30 ± 1.16
Height (cm)	174.1 ± 5.42	160.8 ± 3.88
Weight (kg)	70.81 ± 9.55	53.31 ± 5.09
BMI (kg/m^2)	23.24 ± 2.62	20.58 ± 1.37
Playing experience (months)	21.36 ± 26.89	18.11 ± 17.71
Exposure time of training (hours)	45.43 ± 26.40	31.14 ± 20.27
Exposure time of match (hours)	2.57 ± 1.58	2.74 ± 1.51
Isometric mid-thigh pull test	147.0 ± 32.26	97.84 ± 45.69
Vertical jump test	58.42 ± 8.61	42.44 ± 6.06
Y balance test	589.3 ± 45.72	536.6 ± 29.02
Sit and reach test	34.52 ± 6.45	35.89 ± 7.57
40m speed test	5.76 ± 0.46	6.50 ±0.35
Push-up test	45.24 ± 15.42	18.25 ± 9.59
Illinois test	16.57 ± 0.93	18.29 ± 1.15
Thomas test	16.66 ± 12.52	23.66 ± 4.71
Single leg bridge test	71.11 ± 26.01	55.22 ± 16.46
Yo-yo test, VO_{2max}	43.86 ± 3.18	40.06 ± 1.34
Position (Backs, Forwards)	B:37, F:27	B:8, F:2
Previous injury (Yes, No)	Y:34, N:46	Y:4, N:6

back spinal injury or bulged disk, face laceration; joint dislocation affected the shoulder, elbow and finger and muscle strain commonly related to the hip and shoulder.

3.3.3 Injury characteristics

Twenty-eight players (21M : 7F) sustained a total of 31 injuries over the 28-week season with a total of 495 d absence from rugby activity. Three players were each injured twice. Nine players sustained severe injuries (5M : 4F) with a total of 308 d absence from rugby activity.

3.3.4 Injury incidence

The injury incidence during training and match play was 3.31 and 59.3 injuries per 1000 player hours, respectively. The injury incidence for severe injuries was 0.66 and 22.2 per 1000 player hours for training and matches respectively. The Kaplan-Meier survival curve of the time to initial injury is shown in Figure 3.1. There was a significant difference in time to first injury were compared to time for non-injured players injuries (; $\chi^2 = 120.9$; df = 2, $p < 0.0001$). The mean survival time of players with no injury and with injury was 44.8 hours and 23.11 hours, respectively. The median survival time for severe injuries is 21.8 hours.

3.3.5 Nature of injuries

Lower limb injuries comprised the greatest proportion of injuries (48.4%) and also were the most severe; followed by upper extremity (35.5%); head and face (12.9%)

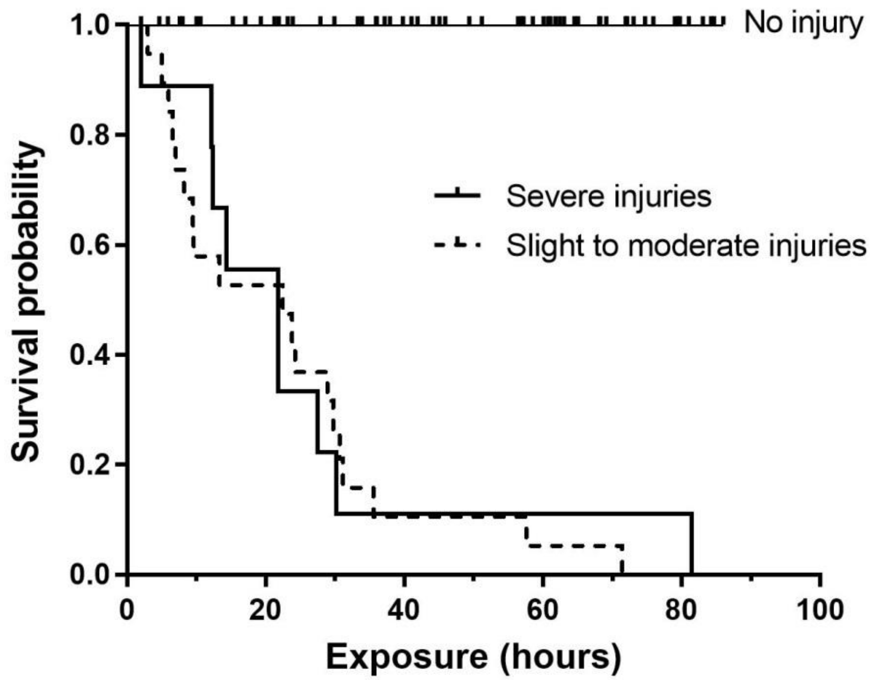

Figure 3.1 Kaplan-Meier survival curves for survival probability of injury during the rugby season for university players

Table 3.2 Injury site for university players

			n	Percentage (%)
Region	Lower limb		15	48.4
		Ankle	7	22.6
		Hamstring	3	9.70
		Knee	4	12.9
		Toe	1	3.20
	Upper limb		11	35.5
		Shoulder	6	19.4
		Fingers	4	12.9
		Hand	1	3.20
	Head and face		4	12.9
		Head	3	9.70
		Face	1	3.20
	Trunk	Upper back	1	3.20

Table 3.3 Injury type for university players

			n	Percentage (%)
Type	Ligament/joint injury		17	54.8
		Ligament sprain	11	35.5
		Ligament tear	4	12.9
		Joint dislocation	2	6.50
	Muscle/tendon injury		6	19.4
		Muscle strain	4	12.9
		Tendon injury	2	6.50
	Concussion		3	9.60
	Fracture		2	6.50
	Contusion		2	6.50
	Laceration		1	3.20

and trunk (3.2%). Ankles (22.6%) and shoulders (19.4%) were the most prevalent sites of injury (Table 3.2). Ligamentous injuries were the most common type of injury encountered (48.4%), followed by muscle strains (12.9%) and concussions (9.6%) (Table 3.3)

All injuries happened to the head were concussion injuries. Muscle strains most commonly affected hamstring muscle (75%) followed by shoulder muscle strains (25%). Ligament sprains occurred most frequently to the ankles (36%) knees (18%) and shoulders (18%). Ligament tears occurred to the knees (50%), shoulders (25%) and fingers (25%). Finger and ankle had a similar proportion (50%) of fractures or dislocations. The body parts affected by contusion were shoulders or upper backs. Laceration to the face accounted for 3% of injuries.

3.3.6 Injury severity/recurrence

Injuries with moderate severity were most prevalent (32.3%) followed by severe injuries (29%). Severe injuries resulted in the greatest lost time of 308 d (Table 3.4). A large proportion of moderate and severe injuries happened in the match, at 60% and 67% respectively.

Nine severe injuries (5M : 4F) were sustained during the season, resulting in an average of 51.3 ± 14.6 days of lost time and the rest of the injuries were slight to moderate injuries (19M : 3F) (Table 3.5). In terms of severe injuries, ligament sprains were the most common type with four injuries (two knees, one ankle, and one shoulder); ligamentous tears to the knee (two injuries); ankle joint dislocation (one injury), ankle fracture (one injury) and finger fracture (one injury).

Table 3.4 Severity and new/recurrent injury for university players

		n	Percentage (%)	Time loss (in days)
Severity	Slight (0-1 d)	2	6.50	2
	Minimal (2-3 d)	2	6.50	6
	Mild (4-7 d)	8	25.8	49
	Moderate (8-28 d)	10	32.3	130
	Severe (> 28 d)	9	29.0	308
Recurrence	New injury	20	64.5	317
	Recurrent injury	9	28.7	177
	From this season	2	6.50	10
	From last season	3	9.70	15
	Other sports injury	4	12.9	150
	Complication of the previous injury	2	6.50	3

Table 3.5 Injury type and location of severe injuries for university players

Injury type		Injury region	n
Ligament/joint injury	Ligament sprain	Knee	2
		Ankle	1
		Shoulder	1
	Ligament tear	Knee	2
	Joint dislocation	Ankle	1
Fracture		Ankle	1
		Finger	1
Total			9

A majority of the injuries observed were new injuries (n = 20) compared to recurrent injuries associated with previous rugby season (n = 3) and from the current rugby season (n = 2). Ligament sprain/tear (26% of all injuries) and muscle strains (10%) were the most common type of new injuries. Ankle sprains and hamstring muscle strain were the most common recurrent injuries occurring from the current season. Shoulder tendon injuries, finger ligament sprains and concussion were recurrent injuries associated from previous season. Injuries related to the complication of previous injuries from rugby were ankle ligament sprain and ACL tear. All injuries that were a recurrence of other sports were severe and resulted in greater time lost than other recurrent injuries from rugby. These included ligament sprains to the knees or ankles (Table 3.4).

3.3.7 Match/training injuries

Of 31 injuries, 15 (48.4%) occurred during training, while the other 16 (51.6%) injuries took place during a match. Ligament/joint injuries were the most common type of injury in both training and match. All concussion injuries happened during matches and all face lacerations occurred during training. (Figure 3.2)

For match injuries, all hamstring muscle strain, concussions and fractures occurred for backs, while forwards sustained ligament sprains. Of the nine severe injuries, six injuries occurred during match play. For training, 10 of the 15 injuries occurred in the second half of the training sessions with ankle ligament/joint injuries as the most common. The three severe injuries (finger fracture, ACL tea, knee ligament

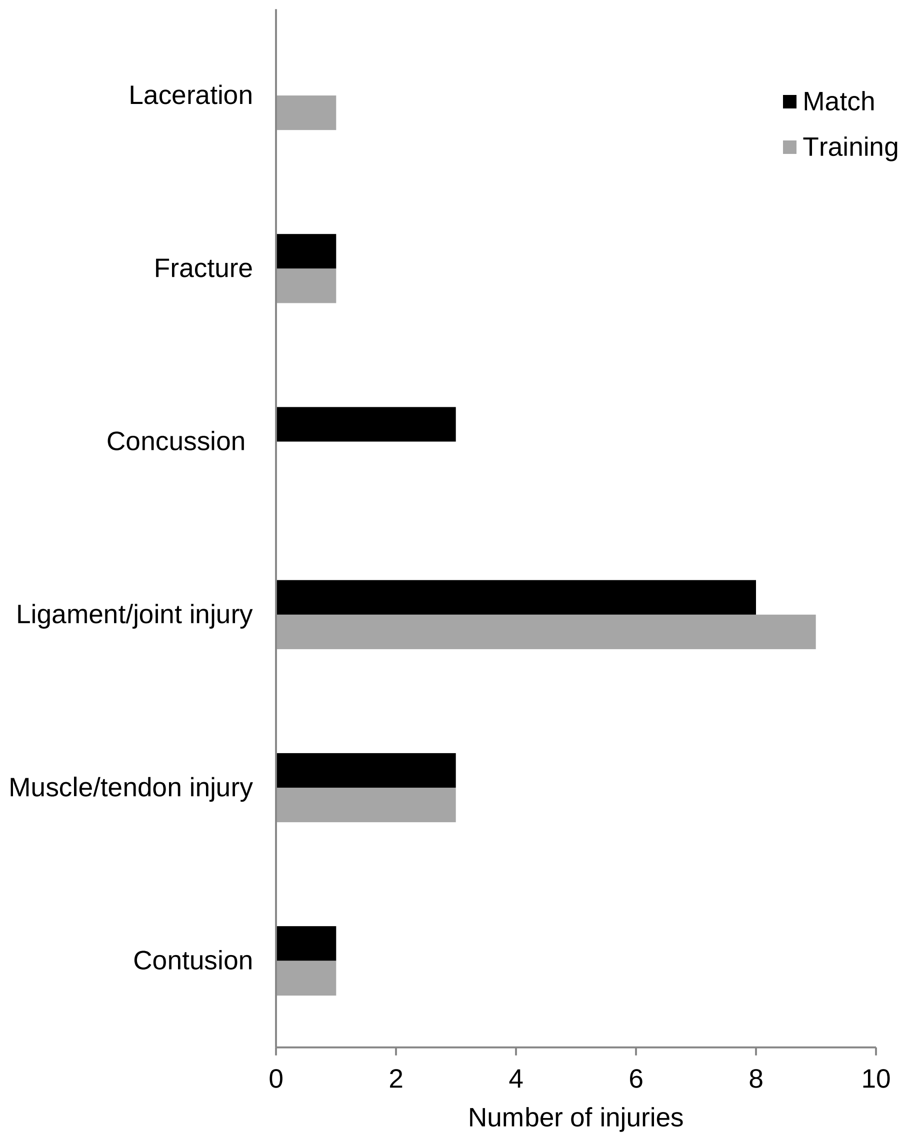

Figure 3.2 Training and match injuries in relation to injury type

sprain) that occurred in the second half of the training. Overall match injuries resulted in greater days lost compared to the training (383 vs. 112 d).

3.3.8 Mechanism of injury

Regarding injury mechanism, 26 injuries (83.9%) were caused by contact, being tackled or tackling contributed to the majority of contact injuries (69%). Of the five non-contact injuries, running (n = 3), changing direction (n = 1), and passing (n = 1) were implicated as the injury mechanism. Furthermore, in 74% of injury events, ground conditions, foul play, fatigue, cold weather, previous injury, inadequate warm-up, and poor skills were suggested as the possible causes of injuries (Table 3.6).

All concussions and fractures and a large proportion of ligament sprains (67%) and muscle strains (74%) occurred due to being tackled or tackling. Six of severe injuries (n = 9) were as a result of contact in a tackle or collision; being tackled alone was responsible for one-third of severe injuries. Ruck, collision non-tackle and running were the next common mechanisms that each one resulted in a severe ligament sprain placed to the ankle or knee. Further, shoulder, head, and ankle were the most common body parts affected by these two phases of playing. In terms of non-contact injuries, running was responsible for 60% of all injuries. Although the number of non-contact injuries was at a minimum, they (running or changing direction) were responsible for 22% of severe injuries placed to the knee.

Table 3.6 Mechanism of injury for university players

Injury mechanism		n	Percentage (%)
Contact		26	83.9
	Tackled	9	29.0
	Tackling	9	29.0
	Collision non-tackle	3	9.70
	Ruck	3	9.70
Non-contact		5	16.1
	Running	3	9.70
	Changing direction	1	3.20
	Passing rugby	1	3.20
Other possible reasons			74.0
	Inadequate ground condition	8	25.8
	Foul play	5	16.1
	Fatigue	3	9.70
	Cold weather	2	6.50
	Inadequate warm up	2	6.50
	Previous injury	2	6.50
	Poor skill	1	3.20

*In 74% of injury cases, players referred to other possible reasons

3.3.9 Treatment of injury

About half of the injured players required health care attention and with 25% needing hospital admission. For severe injuries, 56% required hospital admission while injuries with minimal to moderate severity most frequently treated by health care professionals (general practitioners, physiotherapists or orthopedic specialists). All slight injuries included ligament sprain of fingers and toe did not require any medical attention. Concussions, joint dislocation of ankle, ligament sprain/tear located in ankle or knee and finger fracture were injuries requiring hospital admissions (Table 3.7).

3.3.10 Predictors of severe injuries

Spearman‘s rho analysis revealed association of nine potential variables: gender, height, previous injury, global muscle strength (isometric mid-thigh pull test), hamstring muscle strength (single leg bridge test), lower limb power (vertical jump test), speed (40m speed test), agility (Illinois test) and tightness of hip flexors (Thomas test) with severe injuries (Table 3.8). In order to control multicollinearity, these variables were entered into five models of the Cox regression. The outputs of these models were gender, speed, agility, and hip flexors flexibility which significantly predicted time to serious injuries (n = 9). Female players had a greater risk of severe injury than male players (HR = 8.35; 95% CI = 2.01-34.8). Slower players (adjusted HR = 3.51; 95% CI = 1.17-10.5) and less agile players (adjusted HR = 2.22; 95% CI = 1.26-3.92) had a significantly increased risk of serious injury. The risk of severe injuries increased about 2 or 3.5-fold for less agile and slower players. Lower hip flexors

Table 3.7 Injury treatment for university players

	n	Percentage (%)
Self-treatment	7	22.6
Healthcare attention (by general practitioner, physiotherapist, orthopedic specialist, athletic trainer)	16	51.6
Hospital admission	8	25.8

Table 3.8 Spearman's rho analysis for university players to determine correlation between independent variables with severe injuries (n = 9)

Variables	Correlation coefficient	p
Gender	-0.28	0.004*
Age	-0.09	0.451
Height	-0.23	0.041*
Weight	-0.17	0.137
BMI	-0.05	0.663
Playing experience	-0.03	0.795
Previous injury	0.21	0.050*
Player position	0.03	0.824
Isometric mid-thigh pull test	-0.28	0.008*
Vertical jump test	-0.35	0.001*
Y balance test	-0.16	0.149
Sit and reach test	0.02	0.838
40m speed test	0.18	0.078*
Push-up test	-0.17	0.163
Illinois test	0.18	0.075*
Thomas test	0.22	0.048*
Single leg bridge test	-0.20	0.089*
Yo-yo test, VO_{2max}	-0.06	0.615

*$p < 0.10$

Table 3.9 Predictor variables from Cox regression model for severe injuries for university players

	Predictor variables	Regression coefficient	Hazard ratio (95% CI)	p
Model 1	Height	-0.09	0.91 (0.82-1.00)	0.072
	Agility	0.79	2.22 (1.26-3.92)	0.006*
	Tightness of hip flexors	0.11	1.12 (1.00-1.25)	0.036*
Model 2	Previous injury	1.17	3.21 (0.65-16.04)	0.154
	Speed	0.12	3.51 (1.17-10.5)	0.025*
Model 3	Back muscle strength	-0.26	0.97 (0.94-1.00)	0.057
	Hamstring strength	-0.03	0.97 (0.92-1.01)	0.166
Model 4	Gender	2.12	8.35 (2.01-34.8)	0.004*
Model 5	Leg power	-0.16	0.85 (0.77-0.94)	0.001

*$p < 0.05$

flexibility showed a trend towards risk of severe injuries (adjusted HR = 1.12; 95% CI = 1.00-1.25; Table 3.9).

3.4 DISSCUSION

This prospective study examined the injury incidence and risk factors for injuries in university athletes on rugby-7s teams. All players in this cohort were at least 18 years and received no remuneration. We report the injury incidence, injury types, and nature of injuries these players sustained over one rugby season. The main findings of this study were that female gender, slower speed, decreased agility are predictors for severe rugby-related injuries resulting in a time loss of > 28 d. Our study differs from others (Gabbett & Domrow, 2005; Lopez *et al.*, 2012; Gabbett *et al.*, 2012b) in that we considered only severe injuries for analysis of risk factors. Due to the contact nature of the game, minor to moderate injuries are relatively common. However, we believe that surveillance of more severe injuries is important, particularly as these may have major consequences to the athlete's playing career.

The incidence and severity of injury were considerably lower compared to those reported for 7s players at the professional level (Fuller *et al.*, 2010c). However, the match injury incidence (59.3 injuries per 1000 player hours) is similar to previously reported for amateur players during the course of a rugby-7s tournament series season (55.4 injuries per 1000 player hours) (Lopez *et al.*, 2012). No study has documented the incidence of injury for 7s players during training. However, we observed 3.3 injuries per 1000 player-hours during training. This is comparable but slightly lower than the training incidence reported for collegiate rugby-15s players, which was 5.5 injuries per 1000 player-hours (Kerr *et al.*, 2008).

The most commonly reported injuries occurred in the lower limbs, followed by injuries to the upper extremities. This finding is similar to the injury incidence and injury sites in international rugby-7s tournament players (Fuller *et al.*, 2010c) but the incidence is greater than for amateur rugby- 7s tournament players (Lopez *et al.*, 2012). However, comparison among studies is difficult since the level of play; injury definition and study period are markedly different. In our study, tackling or being tackled resulted in more than half of the injuries. Injuries that result from tackling usually are in the head, neck, or shoulder regions (Peck *et al.*, 2013). Of the shoulder injuries, we observed, five of six were due to tackles, and all four head and face injuries were a result of tackling. Tackling techniques have been found to improve in more experienced players (Hendricks *et al.*, 2012). Players in our cohort had less than two years' experience playing rugby, and this observation may highlight the importance of emphasizing proper execution of tackling techniques. In addition, there is a clear need for research into the biomechanics and injury mechanisms of tackles with the goal of reducing the associated risk. The most common type of injury was to ligaments, which accounted for about half of all injuries and is consistent with previous findings from amateur rugby union studies (Kerr *et al.*, 2008; Lopez *et al.*, 2012).

Our study also revealed that 50% of the severe injuries occurred in the first 21.8 hours of the season. The transition from off-season to high-volume and high-intensity training without sufficient preparation early season can cause injuries. A proper periodization schedule to gradually increase the training intensity could ensure that players have enough time to build physical fitness to adapt to new loads imposed on the body. Significant differences in aerobic power, speed, muscular power and body fat have been reported between professional and amateur rugby-15s players (Gabbett, 2000). Gabbett and Domrow (2005) found that lower speed and maximal aerobic power increased the risk of injury in amateur rugby league players. Although the physical characteristics of rugby-7s players have been examined (Ross *et al.*, 2014), at present, there is no study of the relationship between physical qualities and severe injury risk in amateur players. Results from the present study suggest that speed and agility, as reflected in the 40 m speed test and the Illinois agility test respectively, were strong risk factors for serious injuries. The less agile and slower players had a 2- or 3.5-fold increased risk for severe injury, respectively. Greater injury risk in players slower in speed and agility may reflect their reduced ability to position themselves quickly and correctly before the tackle. The speed characteristics of rugby-7s and 15s players have been reported to be similar over standardized distances (for example, 10 m, 40 m) (Ross *et al.*, 2014), but acceleration appears to be an important component in rugby Sevens. Further studies should examine the acceleration characteristics in rugby-7s players. The incorporation of cognitive components such as decision-making in the agility test will also be useful in discriminating players' abilities. Findings in our study also suggest that the development of speed and agility may help to reduce the risk of severe injuries.

This study also reviewed that female players were at an approximately 8-fold higher risk of serious injuries than males, in agreement with other studies. A recent injury surveillance study (Ma *et al.*, 2016) of the USA Rugby-7s tournament series revealed that in a multiple-match tournament, 93% of all severe injuries occurred in female players during the last match. Non-elite female players also sustained more severe injuries than elite female players (means: 48.4 d time loss *vs*. 22.7 d time loss). Furthermore, the incidence of head and neck injuries in females (16% of all injuries) was higher than in male rugby-7s players (5% of all injuries). A limitation of the study was that the sample size for female players was small (n = 14). As the popularity of women's rugby continues to grow worldwide, (World Rugby, 2016) further research would aid in identifying risk factors and in establishing gender-specific injury prevention strategies.

There was a small association of hip flexor flexibility with injury risk in this study. Hip flexor tightness has been associated with lower extremity injury in male collegiate athletes participating in various sports (Krivickas & Feinberg, 1996). As different sports have specific inherent injury risks, further work is required to clarify the role of iliopsoas tightness in rugby-related injuries.

There are several limitations to this study. The physical test results were collected before the season started and may have changed throughout the playing season. The sample size of the study is relatively small, limiting its statistical power. Areas for further study include injury surveillance throughout consecutive seasons with a larger sample size and inclusion of more female rugby players.

3.5 CONCLUSION

In this study, we report the incidence and severity of injury to university athletes during training and match play of rugby-7s over a rugby season. Female gender, reduced agility, reduced speed, and tightness of the hip flexors were all predictors of severe injuries. Identifying players at risk of injury before the season begins and implementing individualized injury prevention measures may reduce severe rugby-related injuries.

CHAPTER 4

INCIDENCE AND RISK FACTORS OF SEVERE INJURIES FOR SEMI-PROFESSIONAL AND AMATEUR RUGBY-15S PLAYERS

4.1 INTRODUCTION

In Chapter 3, the risk factors associated with severe injuries in amateur rugby-7s players were identified. These include gender, speed, and agility. Female players and those with slower speed and less agility were at greater risk of severe injuries. Nonetheless, these risk factors might not be generalized to other playing level (amateur, semi-professional or professional) or another format of play (7s or 15s).

The physical demands of rugby-7s, as well as tactics and techniques, are completely different from those requirements for rugby-15s. The speed and nature of rugby-7s compared with rugby-15s increased the force of contact (Fuller *et al.*, 2010c). For instance, the severity of concussions was reported to be higher in rugby-7s than rugby-15s with a mean severity of 19.2 and 10.1 d time loss, respectively (Fuller *et al.*, 2010c). The physical features of players such as heavier weight or taller height are evident in rugby-15s players (Fuller *et al.*, 2010c). Thus the difference in physical characteristics and skills influence the physical requirements of the game and injury incidence, type and severity of injuries (Roberts *et al.*, 2013).

High volume of training was identified as possible risk factor for severe injury previously (Brooks *et al.*, 2006). Different levels of play as well as different formats involved different exposure time of training or match with different loading that can result in different injury pattern. Studies have reported that injury rate increases with the increase in competition level (Brooks *et al.*, 2005a; Roberts *et al.*, 2013). The incidence of injury reported to be higher at international level (218/1000 player hours) level than club level (91/1000 player hours) (Brooks *et al.*, 2005a). Also, injury incidence was higher for semi-professional players (21.7/1000 player hours) compared with amateur players (16.6/1000 player hours) (Roberts *et al.*, 2013).

The consequences of severe injuries not only resulted in a loss time in training and games but also increased the burden of direct and indirect medical costs. It is thus necessary to identify the risk factors for severe injuries such that appropriate and effective prevention strategies can be implemented. However, the results from Chapter 3 i.e. the risk factors and injury pattern for the university rugby-7s players might not be applicable to other level and format of playing. In this Chapter, the risk factors for severe injuries at the community level of rugby-15s players including amateur and semi-professional players are examined.

4.2 METHODOLOGY

The study was conducted from September 2015 to March 2016. A total of 135 rugby-15s semi-professional (n = 74) and amateur players (n = 61) with (mean age: 24.14 ± 4.00 years) were prospectively followed during the rugby season of 2015-16. The methodology was similar to that described in Chapter 2. Briefly, four weeks before the start of formal training, the players' demographic data including gender, age, height, weight, playing experience, medical history, history of the previous injury and physical fitness were collected. The players' physical fitness was monitored through 18 physical fitness tests. The following tests were included:

1. Muscle strength and power: Neck flexor muscle endurance test to assess the strength and endurance of neck flexors (Juul *et al.*, 2013); push-up test to assess the strength of the upper body muscles (Gabbett, 2008); isometric mid-thigh pull test to assess

back strength (Darrall-Jones *et al.*, 2015); vertical jump test to assess the leg power (Shaji & Isha, 2009); single leg bridge test to assess hamstring strength (Freckleton *et al.*, 2013); and adductor squeeze test to assess hip adduction strength (Malliaras *et al.*, 2009).

2. Balance and stability: Y balance test to assess dynamic balance (Plisky *et al.*, 2006); single leg hop test to assess dynamic knee stability (Munro & Herrington, 2011); basic plank test to assess the core and back strength (McGill *et al.*, 2012); and side plank test to assess the core strength (McGill *et al.*, 1999).
3. Flexibility and range of motion (ROM): Sit and reach to assess combined lower back and hamstring muscle flexibility (Ayala *et al.*, 2012); Thomas test to assess the flexibility of the hip flexors (Magee, 2014); hip internal rotation test to assess the flexibility of internal rotators (Burns *et al.*, 2011); bent knee fall out test to assess the flexibility of hip adductors (Malliaras *et al.*, 2009); shoulder internal and external rotation test to assess the flexibility of internal and external rotation of the shoulder (Wilk *et al.*, 2009); and ankle dorsiflexion lunge test (Bennell *et al.*, 1998) to assess ankle and calf flexibility.
4. Speed and agility: 40 m speed test to assess acceleration and speed (Glaister *et al.*, 2009); and Illinois test to assess speed and agility (Dawes & Roozen, 2012).

Throughout the season, players participated in regular training and competition, with an average of 88.53 ± 13.72 training hours and 19.90 ± 3.60 match hours. The total exposure time of training was 12,960 hours, and the total exposure time of match was 1,620 hours. For this study, only match injuries were included in this study. All injuries were diagnosed and reported by on-field physiotherapist using OSICS, who attended all matches. Injury details were collected using a standard injury report form as described in Chapter 2. Injured players were followed up until return to rugby activity. In the following section, the results are presented based on the level of play (semi-professional and amateur players).

4.3 SEMI-PROFESSIONAL PLAYERS

4.3.1 Characteristics of semi-professional players

Data were collected from three teams, a cohort of 74 semi-professional players (47M : 27F), with a mean age of 24.0 ± 3.88 year and 129.7 ± 80.8 months of playing experience. Players' demographic data, years of rugby playing experience, exposure time and the previous injury are shown in Table 4.1. The total exposure time of match was 940 hours (with average 15.7 matches per team) over the 28-week period. On average, each player took part in 90.1 ± 11.2 and 19.8 ± 3.08 hours of training and match respectively.

4.3.2 Injury history of semi-professional players

Injury history of the previous season (i.e. 2014-15) were obtained. Forty six (62%) players sustained at least one injury in the past 12 months. Eleven of players (15%) experienced more than one injury. Ankles (18.2%), knees (10.9%) and shoulders (10.9%) were the most common injured body regions. Ligamentous injuries (25.5%) and muscle strains (23.6%) were the most common types of injuries in the last season. The majority of ligament injuries were ankles (43%) and knees (21%); while muscle strains commonly occurred to the hamstrings (23%). Twenty-nine percent of tendon injuries happened to the shoulder or Achilles tendon. Players also reported more severe injuries (n = 2) requiring surgical repair consisting ACL reconstructions and Bankart repair. Two players reported forearm fractures. Other injuries of note were concussions (n = 5), stress fractures (ribs and toe), joint dislocations (shoulder, ankle, and finger), nerve injury and muscle spasm of the neck and meniscus injury of the knee.

4.3.3 Injury characteristics of semi-professional players

During the season 2015-16, 45 players were injured (30M : 15F) totaling to 84 injuries. Twenty-four players suffered from multiple injuries (more than one injury); 14 players injured twice, six players injured three times, three players injured four times and one injured five times. Twelve players (9M : 3F) sustained severe injuries.

With regards to severity for multiple injuries, 14 players had subsequent injury with increased severity (subsequent injury with greater time loss) as compared to 10 players with no increase in severity for subsequent injury (Figure 4.1). There was no significant difference between the proportion of injuries with increased severity (58%) and the proportion of injuries without increased severity (42%) using comparing sample proportion to population proportion ($z = 0.81$, $p = 0.79$).

Table 4.1 Descriptive variables of semi-professional players (n = 74)

Descriptive variables	Males	Females
n	47	27
Age (years)	24.67 ± 3.96	22.78 ± 3.49
Weight (kg)	92.16 ± 14.49	61.13 ± 9.86
Height (cm)	179.5 ± 8.08	163.2 ± 5.31
BMI (kg/m^2)	28.45 ± 3.11	22.92 ± 3.41
Playing experience (months)	159.4 ± 81.49	71.47 ± 35.53
Exposure time of training (hours)	89.19 ± 11.65	91.62 ± 10.45
Exposure time of match (hours)	19.61 ± 3.07	20.05 ± 3.14
Single leg hop test (cm)	294.9 ± 50.17	235.0 ± 40.18
Squeeze test (mmHg)	156.4 ± 39.87	129.7 ± 17.49
Sit and reach test (cm)	32.20 ± 7.06	36.11 ± 8.11
Shoulder ROM test (°)	245.4 ± 44.29	355.33 ± 21.92
Hip IR test (°)	68.70 ± 18.84	87.71 ± 22.86
Push-up test (rep)	44.27 ± 17.00	13.90 ± 9.35
Bent knee fall out test (cm)	29.66 ± 16.57	20.21 ± 5.90
Mid-thigh pull test (kg)	169.5 ± 37.69	96.91 ± 22.31
Single leg bridge test (rep)	59.58 ± 21.62	50.61 ± 24.33
40 m speed test (s)	5.60 ± 0.53	6.46 ± 0.51
Illinois test (s)	16.17 ± 0.82	17.95 ± 1.10
Thomas test (°)	13.51 ± 7.55	14.26 ± 7.20
Basic plank test (s)	167.80 ± 87.26	112.7 ± 54.13
Side plank test (s)	118.6 ± 43.01	101.8 ± 31.59
Y balance test (cm)	569.9 ± 51.59	589.2 ± 54.47
Neck endurance test (s)	102.8 ± 34.11	81.33 ± 42.31
Vertical jump test (cm)	49.70 ± 8.33	39.95 ± 7.10
Ankle dorsiflexion lunge test(cm)	22.00 ± 5.52	25.17 ± 7.62
Position (Backs, Forwards)	B:24, F:21	B:11, F:16
Previous injury (Yes, No)	Y:32, N:13	Y:14, N:13

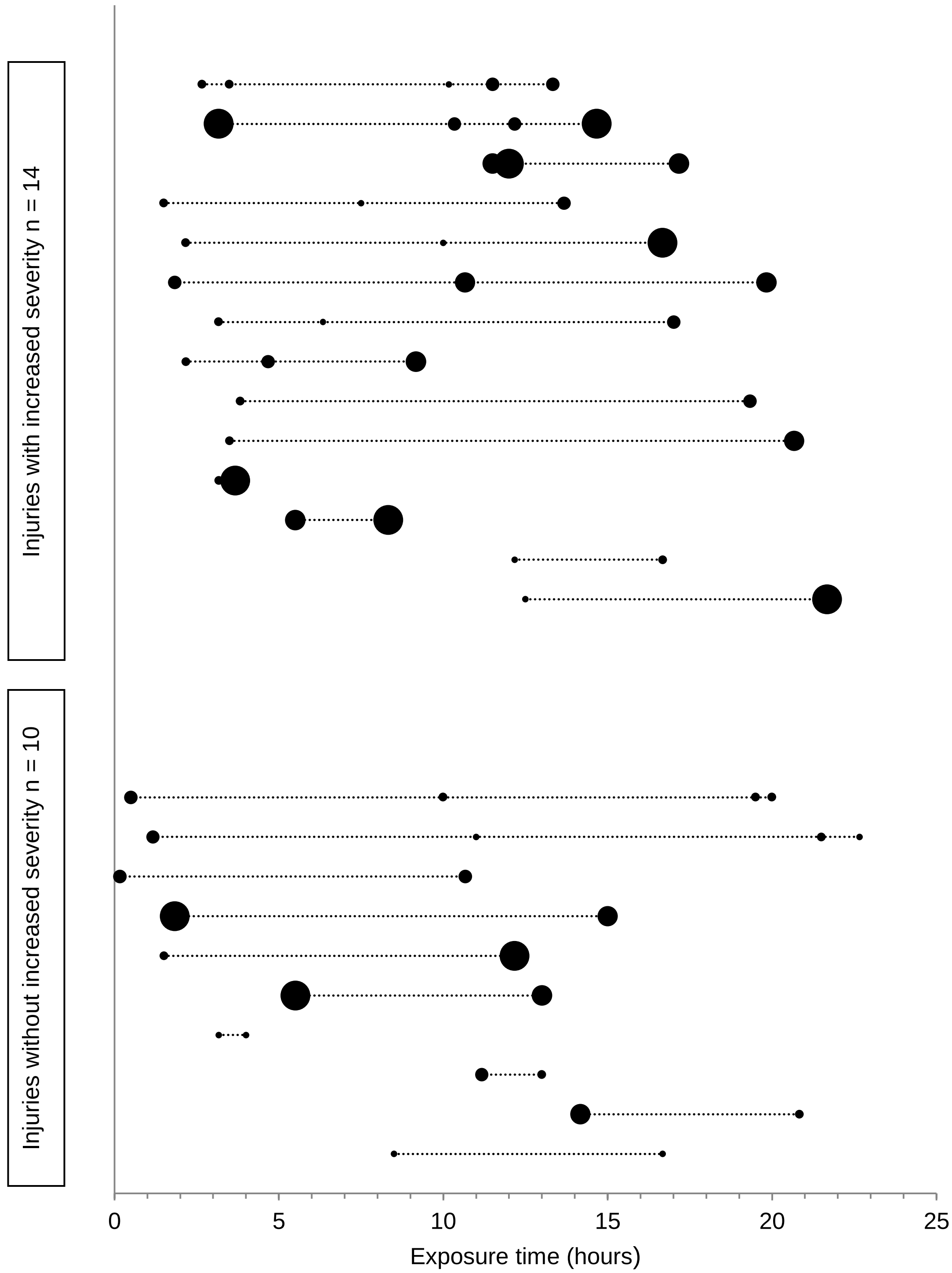

Figure 4.1 Multiple injuries with increased severity or without increased severity for semi-professional players. The size of the dots indicates injury severity.

4.3.4 Injury incidence in semi-professional players

For season 2015-16, the total match hour was 940 hours with injury incidence of 89.4/1000 player hours for match. The injury incidence for severe injuries (> 28 d time loss) was 12.8/1000 player hours.

4.3.5 Nature of injuries in semi-professional players

Lower limb was the most common injured region representing 35.7% of all injuries. This is followed by head and neck (34.5%), upper limb (22.6%) and trunk (7.1%). The head/ face accounted for the highest proportion of injuries (26.2%) followed by the shoulders (14.3%), knees (10.7%) and ankles (8.3%) (Table 4.2).

The majority injury type included ligament sprain injuries (23.8%), contusion (17.9%) and muscle strains (13.1%) (Table 4.3). A large proportion of ligament sprains (75%) were at the ankles (30%), knees (25%) and shoulders (20%). Sixty-four percent of the muscle strains were to the hamstring muscles (46%) or lower leg (18%). Muscle spasm mostly occurred in the lower or upper legs (66%). All tendon injuries were to the shoulders (67%) or ankles (33%). Contusion mostly commonly affected head/face (33%) and knee (20%). Concussion accounted for 38% of all head and neck injuries. Eighty-three percent of laceration injuries affected the head/face. All four dislocations happened to the shoulder joint. There were 5% of injuries causing fracture to the head, fingers, face and foot. Nerve injuries (n = 3) affected the cervical (n = 2) or shoulder (n = 1) region. There was one ACL tear during the season.

Table 4.2 Injury site for semi-professional players

			n	Percentage (%)
Injury Site	Lower limb		30	35.7
		Knee	9	10.7
		Ankle	7	8.30
		Lower Leg	6	7.10
		Hamstring	5	6.00
		Upper Leg	2	2.40
		Foot	1	1.20
	Head and neck		29	34.5
		Head	14	16.7
		Face	8	9.50
		Neck	7	8.30
	Upper limb		19	22.6
		Shoulder	12	14.3
		Fingers	4	4.80
		Upper arm	2	2.40
		Wrist	1	1.20
	Trunk		6	7.10
		Lower back	3	3.60
		Ribs	2	2.40
		Upper back	1	1.20

Table 4.3 Injury type for semi-professional players

			n	Percentage (%)
Injury Type	Ligament/joint injury		25	29.8
		Ligament sprain	20	23.8
		Joint dislocation	4	4.80
		Ligament tear	1	1.20
	Muscle/tendon injury		20	23.8
		Muscle strain	11	13.1
		Muscle spasm	6	7.10
		Tendon injury	3	3.60
	Contusion		15	17.9
	Concussion		11	13.1
	Laceration		6	7.10
	Fracture		4	4.80
	Nerve injury		3	3.60

Ligament sprain was the most common type of injury for upper limb as well as lower limb. The most common type of injury for head and neck was concussion; and contusion was the most common type of injury for the trunk.

4.3.6 Injury severity/recurrence in semi-professional players

The average time loss as a consequence of injury was 10.1 ± 16.1 d (Table 4.4). Slight to mild injuries were ligament sprains and contusions. Moderate injuries included muscle strains and concussions.

Severe injuries (n = 12) resulted in the time lost of 45.8 ± 22.8 (range 30-91 d). Fifty percent of severe injuries occurred in the early part of the season, at the first 8.3 hours of match play. The severe injuries included fracture (n = 3), ligament sprains (n = 3), concussions (n = 2), joint dislocations (n = 2), ligament tear (n = 1) and muscle strain (n = 1). The fracture affected head (30 d time loss), nose (30 d time loss) and foot (91 d time loss). Severe ligament injuries included lumbar facet joint sprain (60 d time loss); knee sprains (106 d time loss). There was an ACL tear that happened in the last game of the season. Concussion and dislocation to the shoulder resulted in 60 and 51 d time loss respectively. Hamstring muscle strain led to 30 d time loss (Table 4.5).

The majority of the injuries were new injuries (75%). For the recurrent injuries, those that happened in the current season were more prevalent and also more severe than those from the last season. Concussion and ankle sprains were the most common recurrent injuries from this season, and shoulder dislocation was the most common recurrent injury from the previous season. The only injury that was complication of a previous injury from rugby was a severe knee injury.

Table 4.4 Severity and new/recurrent injury for semi-professional players

		n	Percentage (%)	time loss (in days)
Severity	Slight (0-1 d)	14	16.7	14
	Minimal (2-3 d)	25	29.8	56
	Mild (4-7 d)	17	20.2	82
	Moderate (8-28 d)	16	19.0	215
	Severe (> 28 d)	12	14.3	458
Recurrence	New injury	63	75.0	558
	Recurrent injury	20	23.8	237
	From this season	11	13.1	145
	From last season	9	10.7	92
	Complication of the previous injury	1	1.20	30

Table 4.5 Injury type and location of severe injuries for semi-professional players

Injury type		Injury region	n
Ligament/joint injury	Ligament sprain	Knee	2
		Upper back	1
	Ligament tear	Knee	1
	Joint dislocation	Shoulder	2
Muscle/tendon injury	Muscle strain	Hamstring	1
Fracture		Head	1
		Nose	1
		Foot	1
Concussion			2
Total			12

4.3.7 Playing position in semi-professional players

The location, type and severity of injuries regarding playing position are shown in Figure 4.2 and Figure 4.3. There was no significant association between playing position and injury occurrence ($\chi^2 = 1.95$, $p = 0.163$). Forwards and backs missed 461 d and 364 d respectively due to injuries, and there was no significant difference between the two groups ($t = -0.88$, $p = 0.381$). Ligament sprain and contusions were most common for forwards; while ligament sprains and muscle strains were most common for backs. Fracture only occurred in the forwards and was the most severe injury (Figure 4.2).

Head/face injuries were the most common injuries and resulted in the most number of missed days (164 d) in forwards while in backs, knee injuries were the most common one leading to the greatest number of lost time (115 d) (Figure 4.3). In terms of type of injury, ligament/joint injuries were most prevalent for second rows, props, and flankers; contusions were most common for props and hookers; concussion injury was similar for props, second rows, and flankers; and muscle/tendon injuries was most common for fly-halves.

All in all, a great proportion of head and neck injuries (69%) and upper limb injuries (74%) happened to forward players and the proportion of lower limb injuries was similar at 50% for both positions. The highest proportion of injuries (18%) was sustained by flankers while centers with 131 d time loss experienced the highest number of missed days compared with others.

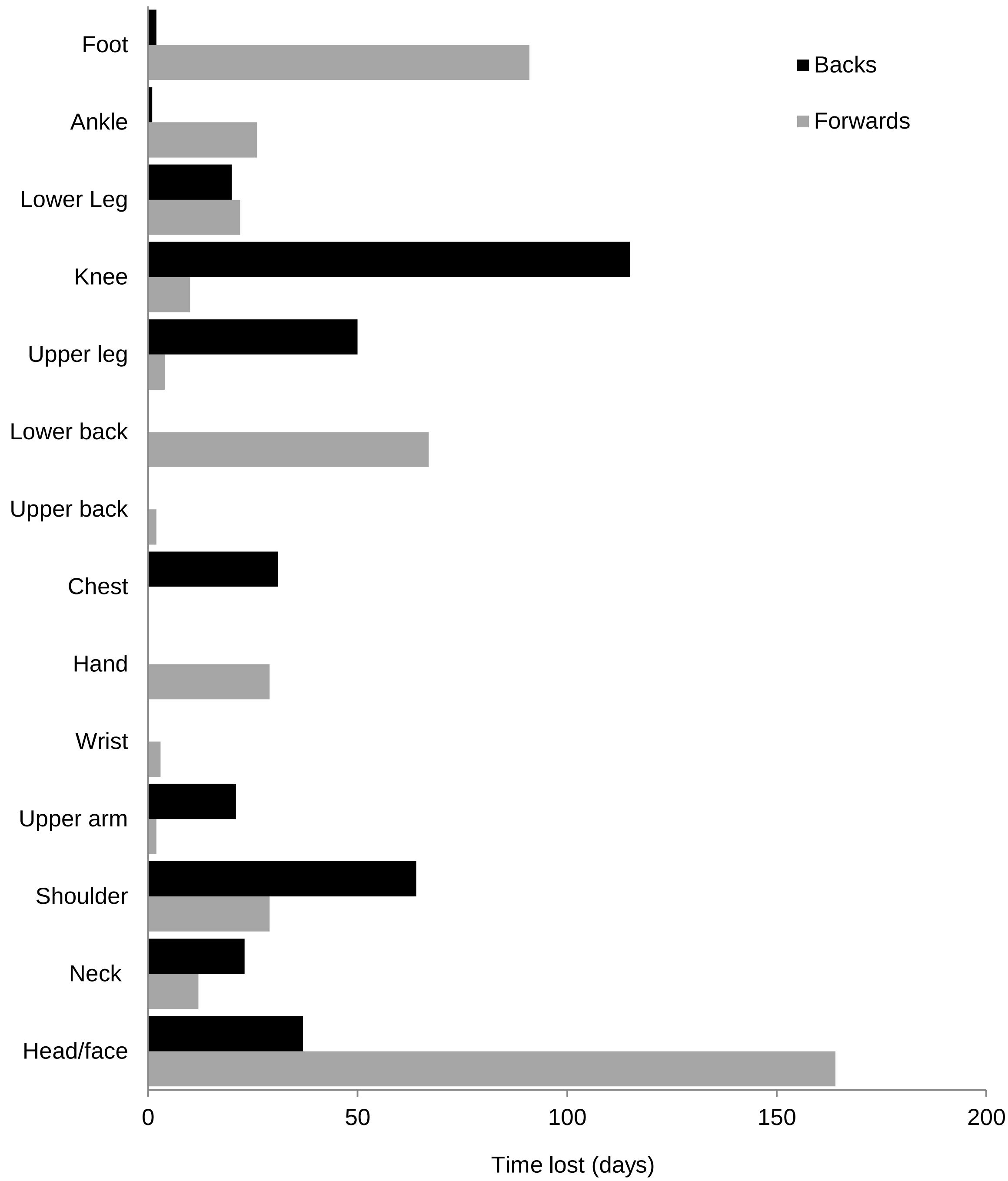

Figure 4.2 Injury severity by anatomical location in terms of position at the semi-professional level

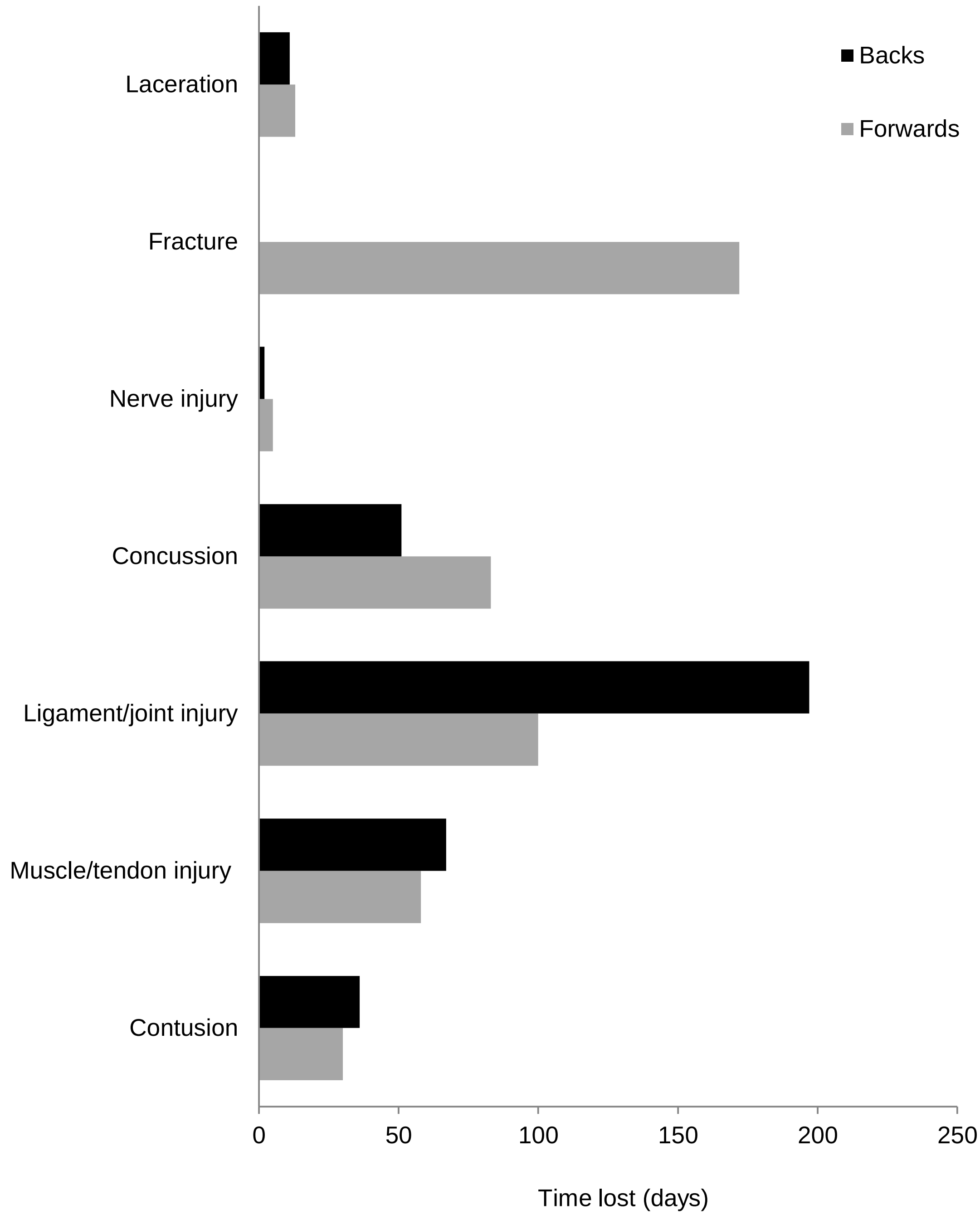

Figure 4.3 Injury severity by type of injury in terms of position at the semi-professional level

4.3.8 Time of match in semi-professional players

The proportion of injuries between first and second half of the match was similar, accounting for 47.6% and 46.4% of all injuries respectively. However, seven of the severe injuries (n = 12) happened in the first half of the match; particularly in the second quarter (n = 5) (Table 4.6). The second quarter also had the greatest percentage of occurrence of injuries (28.6%). It has to take note that two injuries happened during the warm-up period and one of them was severe. The common type of injuries at the first half of the match was ligament/joint injuries (43%) while contusions (26%) were most prevalent in the second half. Further, a large proportion of hamstring strains (80%) happened in the first half of the match or warm up, and a large proportion of concussions (60%) happened in the second half of the match.

4.3.9 Mechanism of injury in semi-professional players

Seventy-one injuries were caused by contact with tackling or being tackled, whereas half of the severe injuries (n = 6) were caused by contact. For severe injuries, being tackled resulted in two head fractures while tackling caused two knee ligamentous injuries. Two shoulder dislocations were due to being tackled or tackling. Ruck and collision non-tackle were the mechanisms responsible for two severe concussions. About 16% of injuries occurred due to non-contact mechanism. Of the 13 non-contact injuries, six injuries happened during running with one severe hamstring muscle strain injury, followed by jumping (n = 2) that led to two severe injuries (foot fracture, knee ligament sprain). Scrum resulted in a lower back ligament sprain.

Table 4.6 Injury time for semi-professional players

	n	Percentage (%)
0-20 min	15	17.9
21-40 min	25	29.8
41-60 min	19	22.6
61-80 min	20	23.8
Warm up	2	2.4
Cool down	2	2.4
Missed data	1	1.2

In connection with the region of injuries, all head and neck injuries, 95% of upper limb injuries, 83% of trunk injuries and 63% of lower limb injuries happened during contact mechanism. Head/face, shoulder, and knee were the most prevalent body parts that affected by contact mechanism, in particular during tackle. Four out of five hamstring injuries was caused by a non-contact mechanism and during running. All concussions, contusions, lacerations and joint dislocations were due to contact events. Inadequate ground condition was suggested to be a possible reason for injuries in 6% of cases. There was no reported injury event due to foul play (Table 4.7).

4.3.10 Treatment for injury in semi-professional players

Apart from fractures that required hospital admission, most commonly concussions and ligamentous injuries needed health care attention (by a general practitioner, physiotherapist, orthopedic specialist, athletic trainer) or hospital admission (Table 4.8).

4.3.11 Predictors of severe injuries in semi-professional players

Possible variables were selected for Spearman's rho test for initial analysis for predictors of severe injuries. Multicollinearity was eliminated for four potential predictor variables with inputting them into two models of Cox regression analysis. These variables were weight, playing experience, basic plank test, and neck endurance test (Table 4.9). No significant predictor for severe injuries for semi-professional players could be found (Table 4.10). The time to the first severe injury is shown on the Kaplan-Meier curve (Figure 4.4).

Table 4.7 Mechanism of injury for semi-professional players

Injury mechanism		n	Percentage (%)
Contact		71	84.5
	Tackled	24	28.6
	Tackling	21	25.0
	Ruck	12	14.3
	Collision non-tackle	8	9.50
	Scrum	4	4.80
	Maul	1	1.20
	Missed data	1	1.20
Non-contact		13	15.5
	Running	6	7.10
	Jumping	2	2.40
	Changing direction	2	2.40
	Passing	1	1.20
	Twisting/turning	1	1.20
	Kicking	1	1.20
Other possible reasons	Inadequate ground condition	5	6.00

Table 4.8 Treatment for semi-professional players

	n	Percentage (%)
Self-treatment	43	51.2
Healthcare attention (by general practitioner, physiotherapist, orthopedic specialist, athletic trainer)	24	28.6
Hospital admission	17	20.2

Table 4.9 Spearman's rho analysis for prediction of severe injuries in semi-professional players to determine correlation between independent variables with severe injuries (n = 12)

Variables	Correlation coefficient	p
Age	0.16	0.175
Weight	0.24	0.044*
Height	0.11	0.342
BMI	0.01	0.910
Gender	0.16	0.176
Playing experience	0.36	0.003*
Playing position	0.17	0.149
Previous injury	0.05	0.670
Single leg hop test	0.03	0.841
Squeeze test	-0.17	0.237
Sit and reach test	-0.19	0.175
Shoulder ROM test	0.15	0.288
Hip IR test	-0.10	0.476
Push-up test	0.18	0.200
Bent knee fall out test	-0.03	0.813
Mid-thigh pull test	-0.08	0.592
Single leg bridge test	-0.06	0.698
40 m speed test	-0.10	0.483
Illinois test	0.01	0.944
Thomas test	-0.09	0.543
Basic plank test	-0.26	0.066*
Side plank test	0.01	0.968
Y balance test	-0.21	0.140
Neck endurance test	-0.27	0.055*
Vertical jump test	-0.18	0.200
Ankle dorsiflexion lunge test	-0.28	0.102

Table 4.10 Predictor variables from Cox regression models for severe injuries in semi-professional players

	Predictor variables	Hazard ratio (95% CI)	p
Model 1	Weight	74.4 (.012-456180)	0.333
	Neck endurance test	87.6 (.017- 446951)	0.305
Model 2	Playing experience	0.03 (0.00-60.09)	0.362
	Basic plank test	35.3(0.017-74760.)	0.362

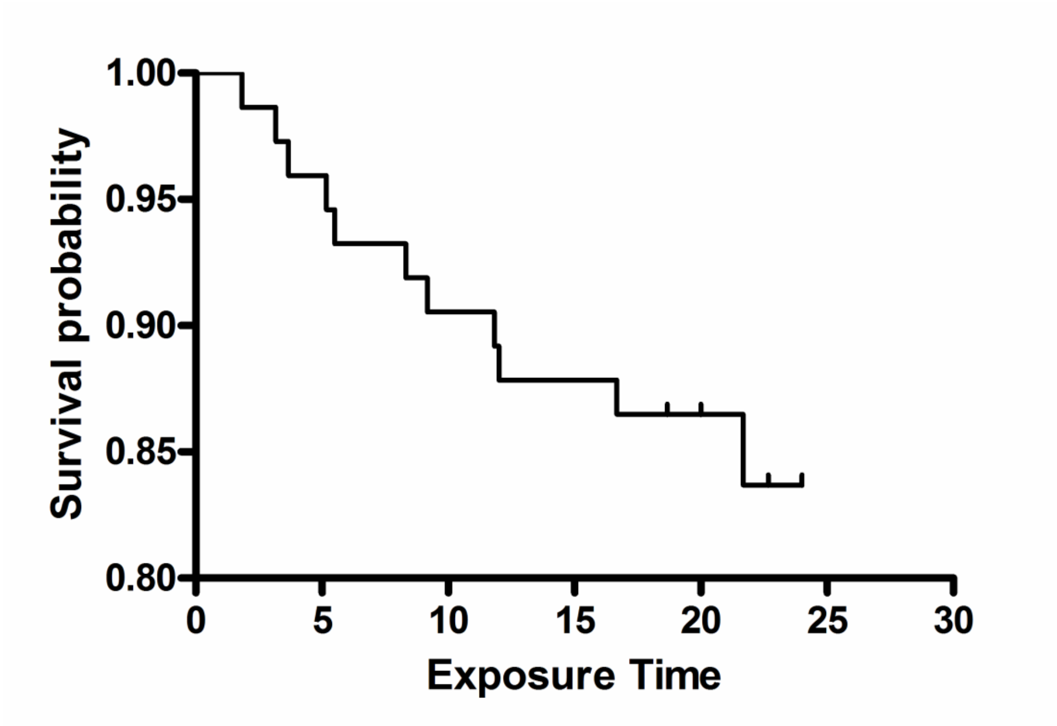

Figure 4.4 Standard Kaplan-Meier curve for time (hours) to the first severe injuries for semi-professional players

4.4 AMATEUR PLAYERS

4.4.1 Characteristics of amateur players

Sixty-one amateur rugby 15-s players (44M : 17F; 24.4 ± 4.17 years) and average playing experience of 64.7 ± 35.6 were followed up over a rugby season. Players' demographic data, years of rugby playing experience, exposure time and the previous injury are presented in Table 4.11. The total exposure time of match was 680 hours (17 matches per team) with an average of 86.7 ± 16.1 training hours and 20.1 ± 4.16 match hours for each player.

4.4.2 Injury history of amateur players

Injury history of the previous season (i.e. 2014-15) were obtained. Thirty one players (58%) had an injury history in the past 12 months. Seven players (12%) sustained more than one injury. The most common region of injuries was ankles (20%), shoulders (11.4%), lower back (11.4%), and foot (11.4%). Ligament sprains (28.6%) and fractures (14.3%) were the most common types of injuries in the last season. Other considerable types of injury were stress fracture to the lower back, joint dislocations (shoulder, elbow, and ankle), spinal injury and meniscus injury of the knee. Two heads injuries were reported but these were not related to concussions.

.

Table 4.11 Descriptive variables for amateur players (n = 61)

Descriptive variables	Males	Females
n	44	17
Age (years)	25.08 ± 3.56	22.19 ± 4.18
Weight (kg)	84.37 ± 15.61	58.91 ± 8.68
Height (cm)	176.4 ± 8.03	161.8 ± 5.49
BMI (kg/m^2)	27.06 ± 3.40	22.47 ± 2.96
Playing experience (months)	115.4 ± 76.49	62.15 ± 37.98
Exposure time of training (hours)	87.86 ± 14.39	89.90 ± 12.25
Exposure time of match (hours)	19.68 ± 3.84	20.36 ± 3.00
Single leg hop test (cm)	305.8 ± 44.50	236.1 ± 37.73
Squeeze test (mmHg)	151.0 ± 32.05	127.2 ± 17.45
Sit and reach test (cm)	32.39 ± 7.15	36.70 ± 7.58
Shoulder ROM test (°)	300.8 ± 63.69	361.4 ± 23.75
Hip IR test (°)	78.84 ± 20.51	88.60 ± 20.62
Push-up test (rep)	42.59 ± 14.61	13.54 ± 9.06
Bent knee fall out test (cm)	22.22 ± 14.21	20.12 ± 6.23
Mid-thigh pull test (kg)	157.6 ± 32.59	92.85 ± 21.58
Single leg bridge test (rep)	62.07 ± 26.54	46.25 ± 21.35
40 m speed test (s)	5.80 ± 0.46	6.53 ± 0.52
Illinois test (s)	16.47 ± 0.98	18.17 ± 1.08
Thomas test (°)	16.01 ± 6.63	14.00 ± 6.35
Basic plank test (s)	153.8 ± 72.48	100.6 ± 48.53
Side plank test (s)	117.0 ± 40.38	97.48 ± 38.73
Y balance test (cm)	597.9 ± 58.14	593.1 ± 48.28
Neck endurance test (s)	102.9 ± 39.88	77.54 ± 42.38
Vertical jump test (cm)	49.17 ± 7.55	38.73 ± 6.74
Ankle dorsiflexion lunge test(cm)	21.19 ± 7.24	23.98 ± 7.06
Position (Backs, Forwards)	B:20, F:24	B:8, F:9
Previous injury (Yes, No)	Y:24, N:20	Y:7, N:10

4.4.3 Injury characteristics of amateur players

There were 39 injured players (28M : 11F) with 78 rugby-related injuries. Twenty-one players had multiple injuries (more than one injury) (Figure 4.5); 10 players injured twice, seven players injured three times, three players injured four times and one injured seven times. Ten players (7M: 3F) sustained severe injuries.

Eighteen players had multiple injuries with increased severity (subsequent injury with greater time loss). The proportion of multiple injuries with increased severity (85%) was significantly higher than those without increased severity (15%) using comparing sample proportion to population proportion ($z = 3.27$, $p = 0.001$).

4.4.4 Injury incidence in amateur players

For season 2015-16, the injury incidence was 114.7/1000 player match hours. The total match hour was 680 hours. The injury incidence for severe injuries was 14.7/1000 player hours.

4.4.5 Nature of injuries of amateur players

Lower limb was the most common region of injury attributing to 35.9% of all injuries followed by head/neck (29.5%), upper limb (25.6%) and trunk (9%). The most prevalent sites of injury were head/face (26.9%), shoulders (14.1%), knees (12.8%) and ankles (9%) (Table 4.12). Ligament sprains (30.8%), contusions (29.5%) and muscle strains (16.7%) were the most common types of injury (Table 4.13).

Most ligament sprains (76%) occurred in the ankles (29%), knees (21%) and shoulders (13%) and elbows (13%). There were two ligament tears (ACL, PCL). The most common regions affected by contusions were the head/face (43%) and shoulders (22%). The most common body part affected by muscle strain was upper back muscle (23%). Twenty-two percent of injuries to the head and neck was concussions. Tendon injuries occurred in shoulders and Achilles tendon. The frequent type of injury for the head and neck was contusion followed by concussion. Muscle strain was the common type of injury in the trunk.

4.4.6 Injury severity/recurrence in amateur players

All injuries led to an average of 14.8 ± 26.2 d time loss (Table 4.14). Contusion at the faces or knees were mostly slight to mild injuries. The most common injury with moderate severity included knee ligament sprains. The severe injuries (n = 10) resulted in 72.2 ± 42.1 d time loss (range between 30-161). Severe injuries most often occurred in the early part of the season, 5 of the 10 severe injuries happened at the first 7.5 hours of the match.

The most common type of severe injuries was ligament injuries (n = 5) followed by fractures (n = 3) and concussions (n = 2). Of the five severe ligament injuries, four was related to the knee with two sprains and two ligament tears placed to the ACL and poster lateral cruciate ligament (PCL) and one to the shoulder with 90 d time loss. Two nose fractures and one finger fracture resulted in 90 and 34 d absence from rugby. Further, two of the five concussions were severe leading to 153 d lost from rugby activity (Table 4.15).

New injuries occurred more often and resulted in a time lost of 1029 d than recurrent injuries (95 d) (Table 4.14). Of eight recurrent injuries, four was recurrence from last season, and four from this season. Knee or ankle ligament sprains were the most commonly recurrent injury from last season, while concussion was the most common recurrent injury from this season. All recurrent injuries from this season were associated with increased severity. These included concussions, ankle and elbow sprains.

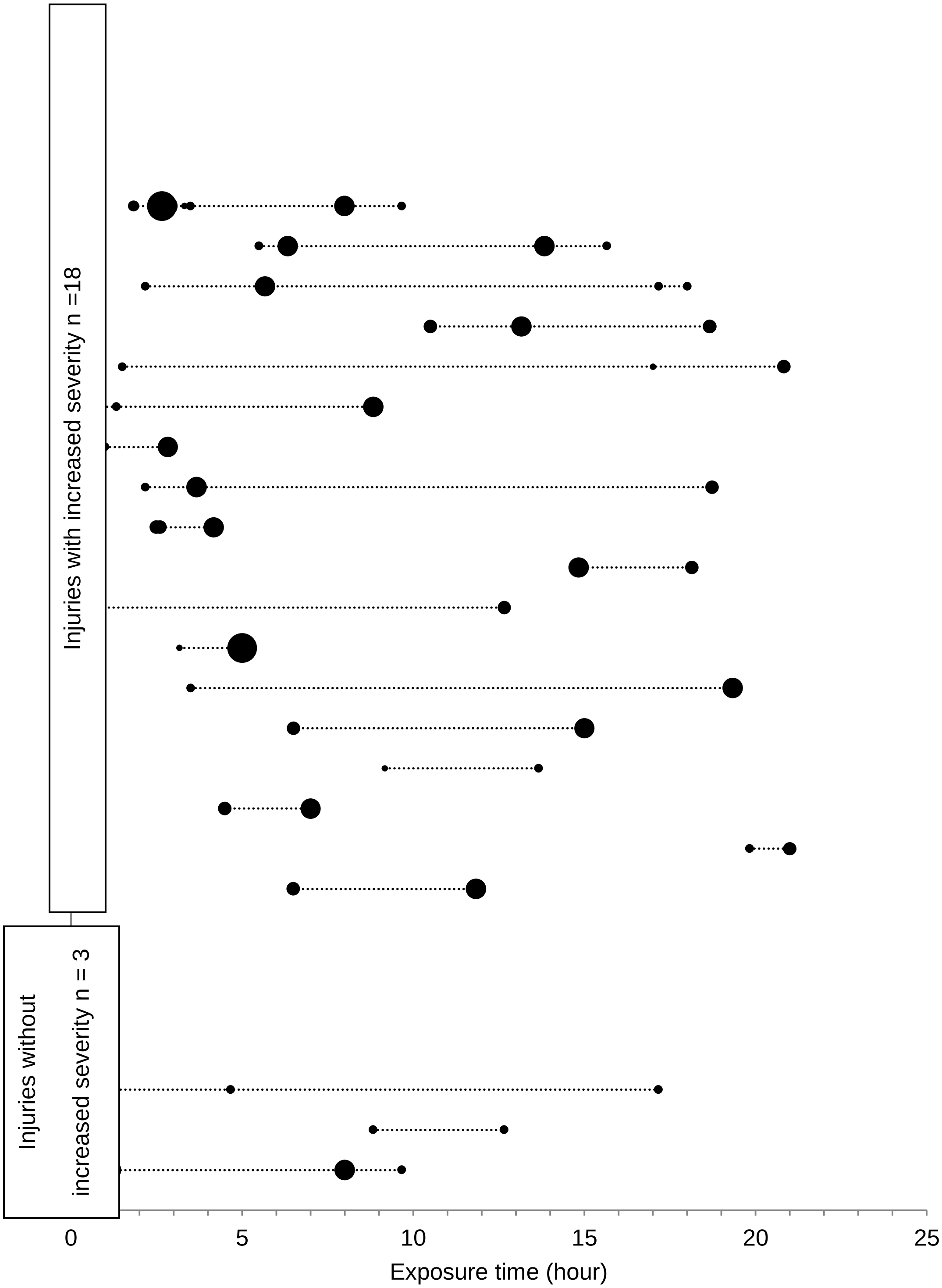

Figure 4.5 Multiple injuries with increased severity or without increased severity for amateur players. The size of the dots indicates injury severity.

Table 4.12 Injury site for amateur players

			n	Percentage (%)
Injury Site	Lower limb		28	35.9
		Knee	10	12.8
		Ankle	7	9.00
		Lower Leg	4	5.10
		Upper leg	3	3.80
		Foot	3	3.90
		Hamstring	1	1.30
	Head and neck		23	29.5
		Face	12	15.4
		Head	9	11.5
		Neck	2	2.60
	Upper limb		20	25.6
		Shoulder	11	14.1
		Fingers	5	6.40
		Elbow	4	5.10
	Trunk		7	9.00
		Upper back	3	3.80
		Lower back	2	2.60
		Ribs	1	1.30
		Chest	1	1.30

Table 4.13 Injury type for amateur players

			n	Percentage (%)
Injury Type	Ligament/joint injury		26	34.7
		Ligament sprain	24	30.8
		Ligament tear	2	2.60
		Joint dislocation	1	1.30
	Muscle/tendon injury		14	20.6
		Muscle strain	13	16.7
		Tendon injury	2	2.60
		Muscle spasm	1	1.30
	Contusion		23	29.5
	Concussion		5	6.40
	Fracture		4	5.10
	Laceration		3	3.80

Table 4.14 Severity and new/recurrent injuries for amateur players

		n	Percentage (%)	time loss (in days)
Severity	Slight (0-1 d)	7	9.00	7
	Minimal (2-3 d)	24	30.8	53
	Mild (4-7 d)	18	23.1	92
	Moderate (8-28 d)	19	24.4	322
	Severe (> 28 d)	10	12.8	650
Recurrence	New injury	70	89.7	1029
	Recurrent injury	8	10.2	95
	From last season	4	5.10	74
	From this season	4	5.10	21

Table 4.15 Injury type and location of severe injuries for amateur players

Injury type		Injury region	n
Ligament/joint injury	Ligament sprain	Knee	2
		Shoulder	1
	Ligament tear	Knee	2
Fracture		Nose	2
		Finger	1
Concussion			2
Total			10

4.4.7 Playing position in amateur players

The severity of injury regarding playing position is summarized in Figure 4.6 and Figure 4.7. There was no significant association between playing position and injuries being sustained ($\chi^2 = 0.003$, $p = 0.958$). Forwards missed more days due to injuries (739 d) compared with backs (385 d) but this was not significant ($t = 1.04$, $p = 0.302$). Ligament/joint injuries resulted in similar lost in both playing positions Concussions in forwards and fractures in backs caused the highest number of missed days (Figure 4.7).

In terms of location of the injury, forwards most often sustained shoulder injuries (with 137 d time loss); while knee and head/face injuries resulted in more missed days, accounting for 239 and 224 d respectively. In backs, head/face was the most common site and also sustained the greatest time lost (111 d time loss) with knee injuries resulting in 103 absent d (Figure 4.6).

More specifically, contusions most commonly happened to flankers; muscle/tendon injury occurred most commonly in hookers; second rows and flankers sustained more ligament/joint injuries than other positions; most concussion injuries happened to second rows or wings; and most fractures happened to wings. Overall, most injuries occurred to wings and after props compared to other positions. A high proportion of upper limb injuries (70%) were sustained in forwards.

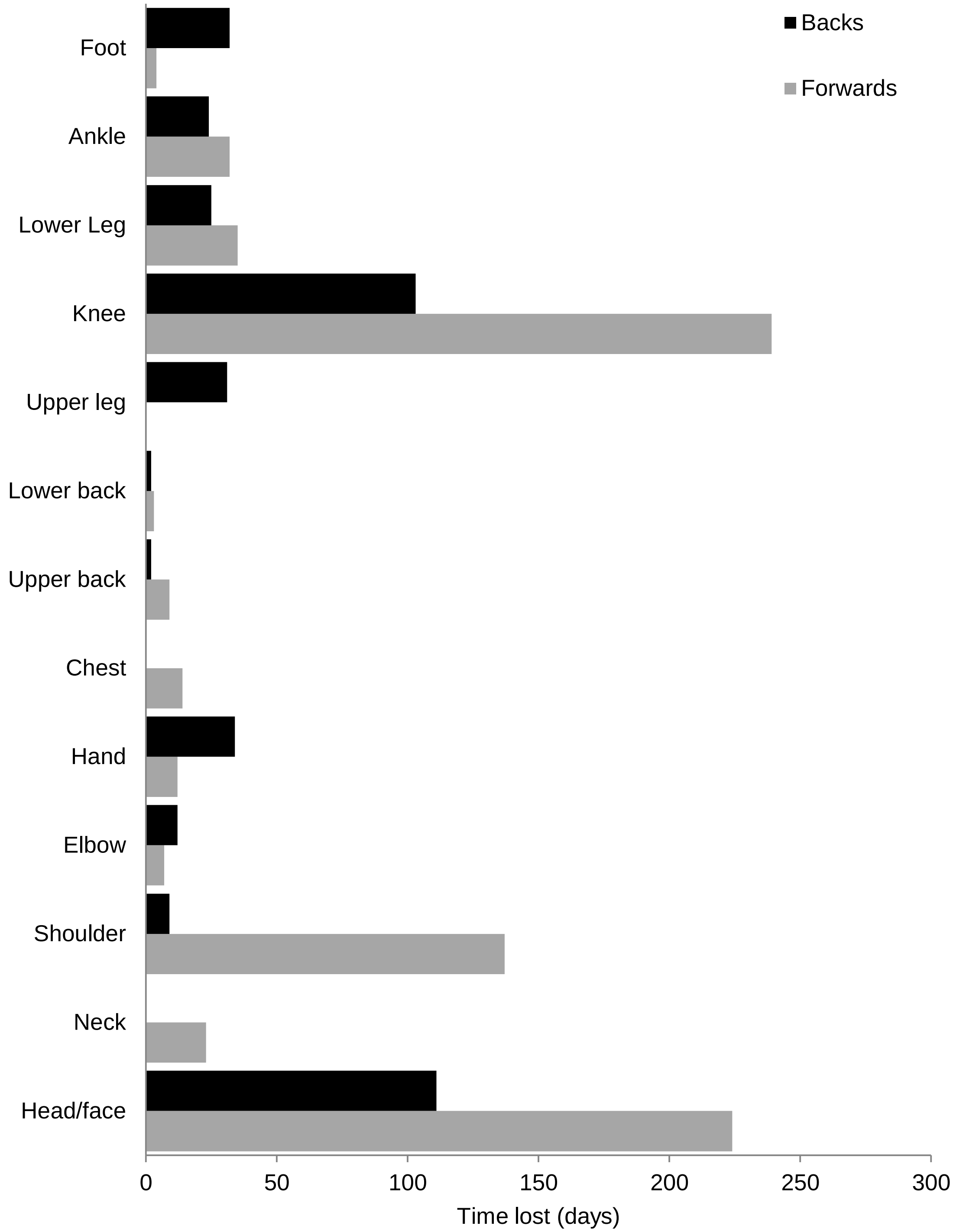

Figure 4.6 Injury severity by anatomical location in terms of position in amateur players

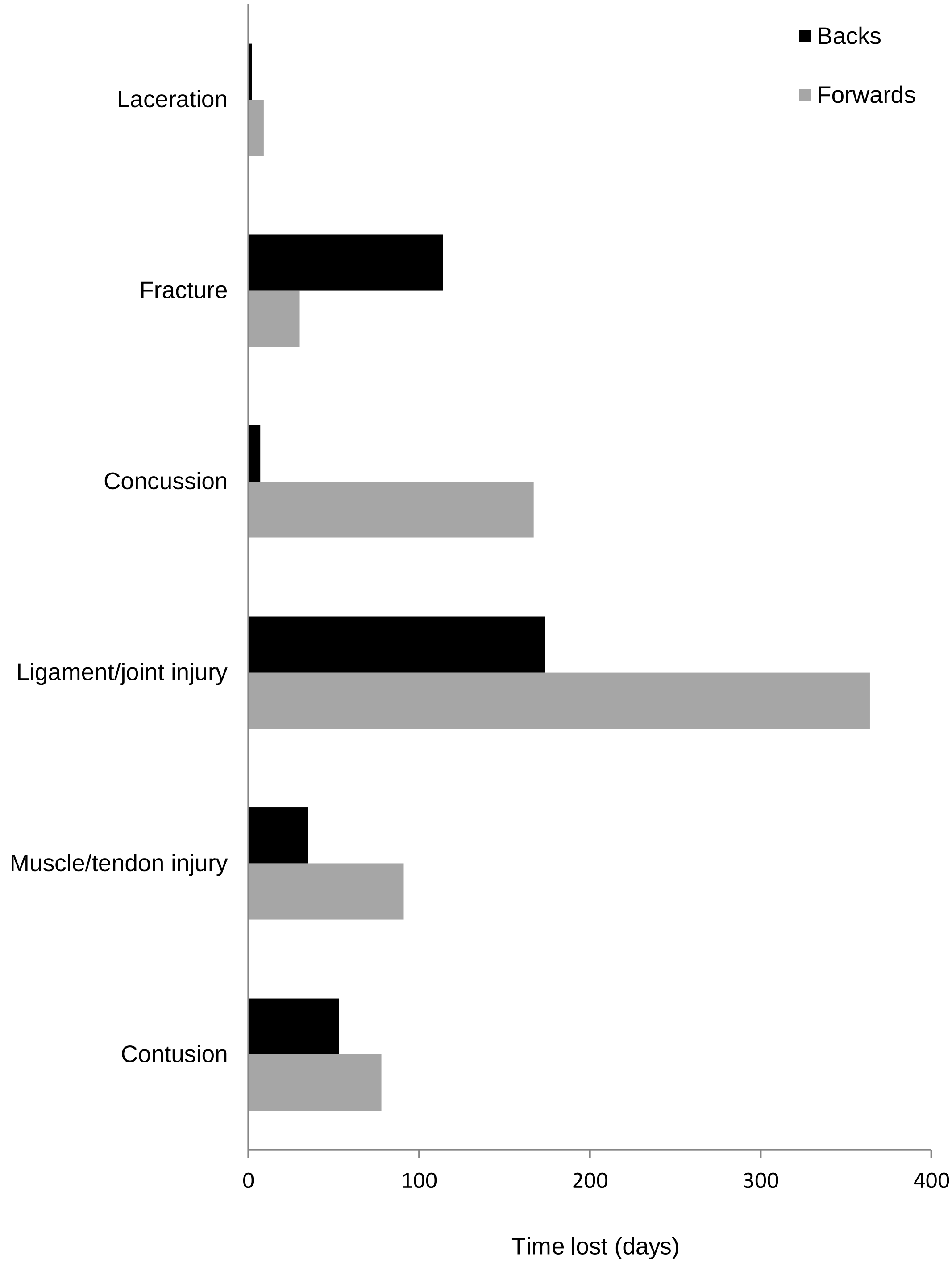

Figure 4.7 Injury severity by type of injury in terms of position in amateur players

4.4.8 Time of match in amateur players

The incidence of injuries was similar in two halves of the match (Table 4.16). Ligament/joint injuries were the most common type of injuries in both halves accounting for 42% in the first half and 29% in the second half. In terms of location of injuries, knees were the most commonly injured site in the first half and head/face in the second half. Eighty percent of concussions occurred in the second half of the match.

4.4.9 Mechanism of injury in amateur players

A great proportion of injuries were sustained due to contact events, particularly during tackling or being tackled (Table 4.17). All severe injuries due to tackling occurred to the head resulting in two nose fractures and a concussion. A severe ligament sprain to the knee was caused by being tackled. Ruck and collision non-tackle were the next common mechanisms that resulted in serious injuries as well; a ligament tear (PCL), a fracture (finger) and a shoulder ligament sprain respectively. Even though the number of injuries due to maul mechanism were minimal but it caused a severe concussion.

For non-contact mechanisms, although it caused a small number of injuries, it was responsible for 20% of severe injuries. Twisting/turning contributed to the majority of non-contact injuries and resulted in two severe ligamentous injuries to the knee (ACL tear and sprain).

In terms of site of injury, all the head, neck and trunk injuries, 95% of upper limb injuries and 79% of lower limb injuries was due to contact mechanism. Head/face, shoulder, and knee were common injured parts during contact phase. Thirty percent of knee injuries occurred during non-contact mechanism in particular in twisting and turning. All dislocations, concussions, fractures and lacerations happened due to contact mechanism. Six percent of the injured players mentioned that inadequate ground condition and fatigue were other possible reasons for their injuries. Only 3% of injuries were associated with foul play.

4.4.10 Treatment for injury in amateur players

Apart from fractures that must be attended by hospital admission the rest of the injuries, mostly concussions and ligament/joint injuries, required health care attention (by a general practitioner, physiotherapist, orthopedic specialist, athletic trainer) or hospital admission (Table 4.18).

4.4.11 Predictors of severe injuries in amateur players

Potential variables were selected for Spearman's rho analysis for predictors of severe injuries. Three potential variables were included: weight, single leg bridge test, and Y balance test and inputted for Cox regression analysis (Table 4.19). Weight was a significant predictor for rugby related injury in amateur players. The risk of injury increased for players with greater mean body weight (HR = 6.84; 95% CI = 1.8-26.3). Females with body weight > 58.9 kg and male players > 84.4 kg were at higher risk of severe injuries. Players with lower balance ability sustained more severe injuries (HR = 4.38; 95% CI = 1.1-17.9). Females with Y balance performance < 593.1 cm and males with a score < 597.9 cm were at higher risk of severe injuries (Table 4.20). Significant predictors of severe injuries are shown in Figure 4.8 and Figure 4.9.

Table 4.16 Injury time for amateur players

	n	Percentage (%)
0-20 min	14	17.9
21-40 min	22	28.2
41-60 min	20	25.6
61-80 min	21	26.9
Cool down	1	1.30

Table 4.17 Mechanism of injury for amateur players

Injury mechanism		n	Percentage (%)
Contact		71	91.0
	Tackled	23	29.5
	Tackling	22	28.2
	Ruck	10	12.8
	Collision non-tackle	7	9.00
	Scrum	5	6.40
	Maul	3	3.80
	Punch	1	1.30
Non-contact		7	9.00
	Twisting/turning	4	5.10
	Running	1	1.30
	Passing	1	1.30
	Kicking	1	1.30
Other possible reasons			9.00
	Inadequate ground condition	2	3.00
	Fatigue	2	3.00
	Foul play	2	3.00

Table 4.18 Treatment for amateur players

	n	Percentage (%)
Self-treatment	42	53.8
Healthcare attention (by general practitioner, physiotherapist, orthopedic specialist, athletic trainer)	18	23.1
Hospital admission	18	23.1

Table 4.19 Spearman's rho analysis for amateur players to determine correlation between independent variables with severe injuries (n = 10)

Variables	Correlation coefficient	p
Age	-0.17	0.186
Weight	0.30	0.024*
Height	0.15	0.245
BMI	0.20	0.141
Gender	-0.21	0.872
Playing experience	0.08	0.522
Playing position	-0.05	0.688
Previous injury	0.17	0.191
Single leg hop test	0.23	0.120
Squeeze test	0.06	0.680
Sit and reach test	-0.17	0.246
Shoulder ROM test	-0.19	0.206
Hip IR test	0.10	0.506
Push-up test	0.09	0.569
Bent knee fall out test	0.14	0.336
Mid-thigh pull test	0.18	0.219
Single leg bridge test	-0.27	0.064*
40 m speed test	-0.05	0.723
Illinois test	-0.08	0.614
Thomas	0.06	0.678
Basic plank test	-0.16	0.280
Side plank test	-0.19	0.197
Y balance test	-0.29	0.046*
Neck endurance test	0.04	0.790
Vertical jump test	0.13	0.391
Ankle dorsiflexion lunge test	0.01	0.964

*$p < 0.10$

Table 4.20 Predictor variables from Cox regression model for severe injuries in amateur players

Predictor variables	Regression coefficient	Hazard ratio (95% CI)	p
Weight	0.89	6.84 (1.78-26.3)	0.005*
Y balance test (sum of two sides)	1.92	4.38 (1.07-17.9)	0.040*
Single leg bridge test (sum of two sides)	1.48	2.45 (0.28-21.5)	0.420

*p < 0.05

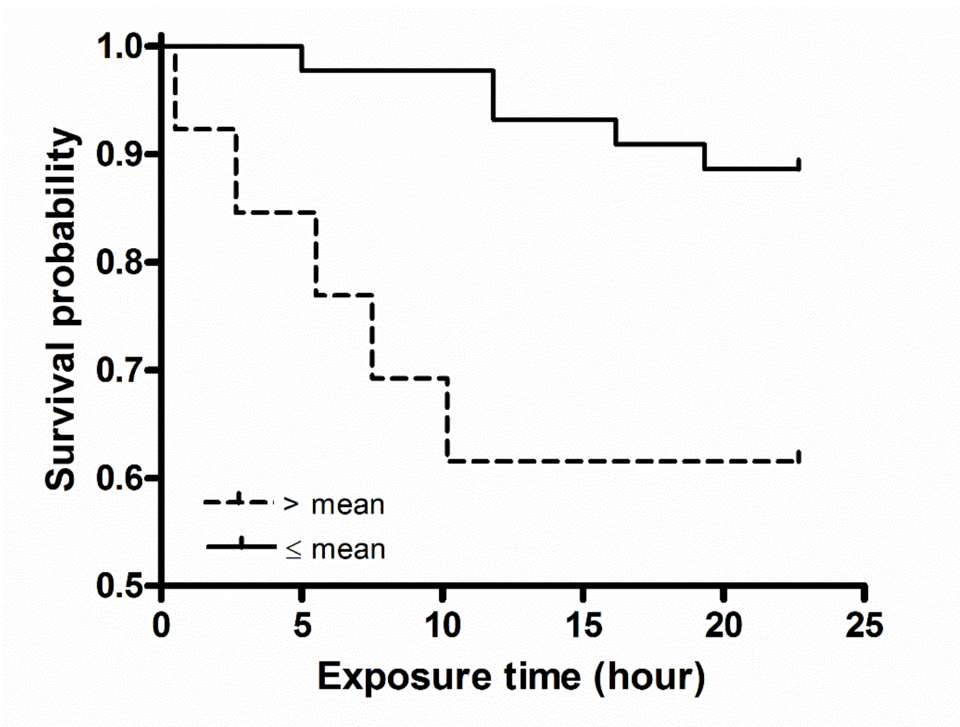

Figure 4.8 Standard Kaplan-Meier survival curve for severe injuries for amateur players with higher mean weight as a significant risk factor.

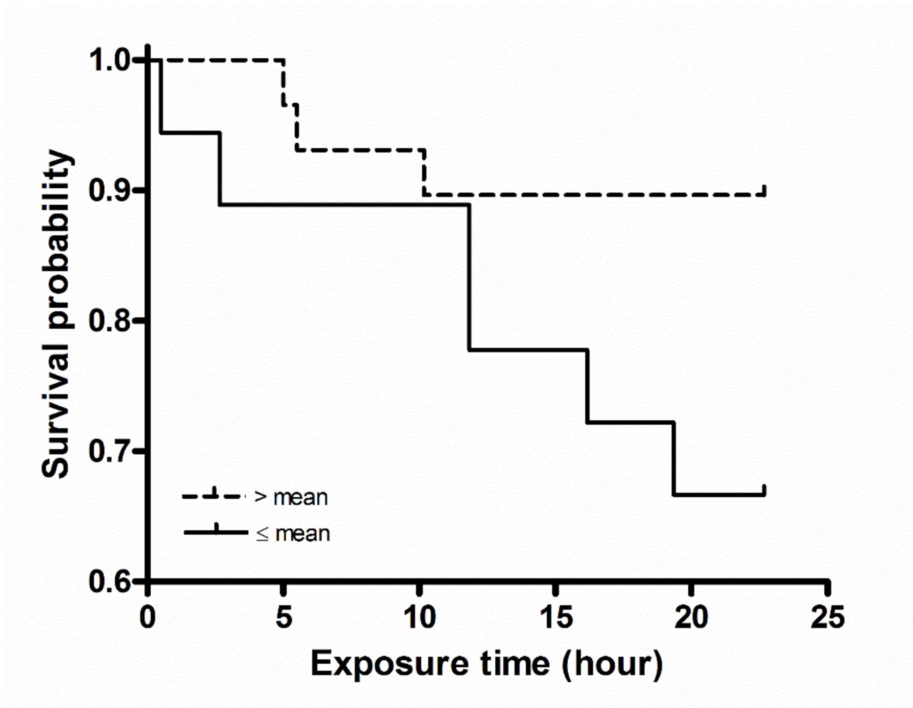

Figure 4.9 Standard Kaplan-Meier survival curve for severe injuries for amateur players with poorer Y-balance mean score as a significant risk factor.

4.5 DISCUSSION

This study reported the injury incidence and risk factors for injuries in community rugby categorized as semi-professional and amateur levels. The main finding of this study was that greater body weight and poor dynamic balance ability are significant risk factors for severe injuries at the amateur level rugby-15s players while in the semi-professional level there was no significant predictor for severe injuries. During the competition season, the incidence of injury in amateur players was higher than semi-professional level with 114.7 and 89.4/1000 player hours respectively. Furthermore the injury incidence was higher from what had been reported in amateur players ranging 16.6-52.3/1000 player hours (Takemura *et al.*, 2009; Roberts *et al.*, 2013; Swain *et al.*, 2016), and semi-professional players ranging between 21.7-54.1/1000 player hours (Schneiders *et al.*, 2009; Roberts *et al.*, 2013; Smith *et al.*, 2014). The differences can be due to the methodological variety, use of a different time lost definition may result in a difference in incidence of injury. In our study injury definition was any physical complaint resulted in at least one-day time loss from rugby activity following the day after the injury irrespective of whether training sessions or match were actually scheduled. However, Roberts *et al.* (2013) defined time-loss injury as any injury resulting in an absence for one week or more from match play, or Smith *et al.* (2014) recorded those injuries that resulted in 8 d or more absence from match play. In the study of Schneiders *et al.* (2009) injury is defined as any event that required medical attention or missed one scheduled training or match. Takemura *et al.* (2009) considered that event as an injury that caused to miss one scheduled training session or match irrespective the need for medical attention; or Swain *et al.* (2016) defined injury as any physical complaint irrespective of the need for medical care or time-loss from rugby activities. Another possible difference in our results with previous studies could be the effect of gender. In our studies, we recruited both male and female players, but for other studies, the investigators only recruited male players (Schneiders *et al.*, 2009; Roberts *et al.*, 2013; Smith *et al.*, 2014; Swain *et al.*, 2016).

Our finding demonstrated that at both playing levels, most injuries occurred to the lower limb followed by head and neck injuries; the most common anatomical sites of injury were head/face, shoulders, and knees. The most prevalent type of injuries was ligament injuries to the ankles and knees for both semi-professionals and amateur players; with knee ligament injuries as the most common severe injuries. This finding is consistent with reports from the epidemiological studies for community level rugby union semi-professional and amateur players (Roberts *et al.*, 2013; Swain *et al.*, 2016); as well as the professional players (Kaux *et al.*, 2015). At amateur level, concussions accounted for 6% of all injuries which was comparable with the United Kingdom and New Zealand community level ranging between 5-8% (Chalmers *et al.*, 2012; Roberts *et al.*, 2013; Swain *et al.*, 2016). However, we found that 13% of all injuries in the semi-professional players were concussions. This was almost two-fold more than that reported in the semi-professional players ranging between 5.5-7% (Schneiders *et al.*, 2009; Roberts *et al.*, 2013). These studies consider injuries that led to more than one week absence (Roberts *et al.*, 2013) or missing a scheduled training session or match (Schneiders *et al.*, 2009) while in our study, time lost considered as one day after injury irrespective of whether training or match was actually scheduled.

Tackle is the noted mechanism associated with injury in the present study which is comparable with the results of rugby studies across different levels of play (Schneiders *et al.*, 2009; Roberts *et al.*, 2013; Williams *et al.*, 2013). Head, shoulders, and knees were the most common body regions that were affected by being tackled or tackling, and this is consistent with other studies (Fuller *et al.*, 2007a; Peck *et al.*, 2013). Our findings indicated that ball carriers and tacklers frequently sustained contusions or ligament sprains. Ruck was another common mechanism of injuries that frequently resulted in contusion in head/face and ligament sprain of the ankle. Emphasis on contact skills fundamentally on tackle and ruck can be helpful to prevent contact injuries. Analysis of tackle circumstance utilizing video recordings should be considered in particular for amateur players (Takemura *et al.*, 2009). For non-contact injuries, running was the most common non-contact mechanism in semi-professional players. Hamstring strains mostly happened during the running phase. Regarding most hamstring injuries happened in the first half of the match and one was severe, it seems that adequate warm up may be substantial to decrease the risk of injury (Chalmers *et al.*, 2012). In amateur players, mechanism of twisting or turning was common, and resulting in a severe knee ligament sprain and an ACL tear. These severe knee injuries as well as an ACL tear in semi-professional level happened in the second half of the match. This finding was in agreement with other studies (Brooks *et al.*, 2005a; Dallalana *et al.*, 2007) that most knee injuries as well as the severe ones sustained in the second half of the match and highlighted fatigue as a possible reason for these types of injuries.

Our results showed that one-third of the players (32% semi-professional, 34% amateur players) sustained more than one injury over the season. Over half of the injured players sustained subsequent injuries with increased severity. In amateur players, this trend was significant, 85% of multiple injuries were associated with increased severity. This highlights the significance of full recovery before returning to full participation. Deficits in muscle strength or proprioception lead to alterations in function and motor control (Fulton *et al.*, 2014). Additionally, residual deficits in physical fitness or proprioception after a previous injury may result in injury in another region (Hägglund *et al.*, 2006). Also injury may impose psychological responses such as negative mood state, lower self-esteem and greater levels of anxiety (Johnston & Carroll, 1998). This has been reported that in rugby, the frequency of injury was related to anxiety and depression (Lavallée & Flint, 1996). Thus, the adverse psychological effects of injury may result in recurrent or new injuries. Furthermore, the pressure from coaches for the early return to training without adjustment of the intensity of training may also increase the risk of injury (Gerrard *et al.*, 1994). From this point of view, monitoring the players with an injury history is a necessity to ensure that they are fully rehabilitated before returning to play (Lee *et al.*, 2001; Quarrie *et al.*, 2001; Chalmers *et al.*, 2012).

Our results demonstrated that the proportion of severe injuries were 14% for semi-professional and 13% for amateurs. This is comparable to those reported before for amateur rugby union players (16%) (Swain *et al.*, 2016). The incidence of severe injuries at both levels of play were similar; i.e. 12.8 and 14.7/1000 player hours for semi-professional and amateur players respectively. For missed time, injures at the amateur level resulted in greater time loss compared to semi-professional level players with the mean time loss of 72.2 d and 45.8 d respectively.

Our finding was also consistent with other studies that severe injuries occurred in the early part of the season (McManus & Cross, 2004). We found that 50% of severe injuries happened at the first 8.3 hours (first seven matches) and 7.5 hours (first six matches) of the match exposure time for semi-professional and amateur players respectively. There is the possibility that rugby players in community level are not enough prepared for the competitive playing in the early part of the season. Another possible reason is the survival effect; it means that those players prone to injury sustain an injury in the early part of the season, so their match exposure will be decreased for further injury (Roberts *et al.*, 2013). Additionally, in our study, forwards and backs did not have significant difference in terms of sustaining an injury, this was in agreement with previous studies (Fuller *et al.*, 2010c; Brooks & Kemp, 2011; Whitehouse *et al.*, 2016).

Our findings revealed no significant predictors for severe injuries in semi-professional level while weight, Y balance test was identified as a significant predictor for severe injuries in amateur level. Female players with body weight > 58.9 kg and male with body weight > 84.4 kg sustained 6.8 folds more serious injuries than lighter players. Our findings are comparable with findings from other investigations; the risk of injuries increased for players with greater body weight (Quarrie *et al.*, 2001; Gabbett *et al.*, 2012b; Archbold *et al.*, 2015). Force of tackle depends on body weight, speed and how fast the players can stop movement, so high-speed and high-impact tackles associated with a greater risk of injury (Fuller *et al.*, 2007a; Quarrie & Hopkins, 2008). A possible reason is that heavier weight during contact produce greater force that may result in an injury. Another explanation is that the larger players are used more during matches and because of increase of their exposure in a higher volume of contact; they deal with the greater risk of injuries. One possible suggestion is that the match load should be modified for this subgroup of players (heavier players) in order to decrease the risk of injury (Gabbett *et al.*, 2012b; Archbold *et al.*, 2015).

Y balance test had been suggested as an effective method to predict lower limb injuries in basketball players as well as football players (Plisky *et al.*, 2006; Pollock, 2010). Results from the present study revealed that players with less balance ability, for females < 593.1 cm and males < 597.9 cm, had a 4.4-time increased the risk for severe injuries. Research indicates that the further the distance can reach, the better the players' functional performance (Hertel *et al.*, 2006). It is suggested that developing functional movement conditioning and also technical components such as tackle, ruck, scrum and other isolated skills is very crucial for rugby players.

We found no significant predictors of severe injuries for the semi-professional players. It could be related to the fitness level, as these players are involved in more structured training in terms of physical, technical and tactical training making them more capable of dealing with risk situation and could be protective against injury (Brooks *et al.*, 2005a), so physical fitness tests were not effective to predict injury in this population. It has to take note that since the fitness data collected in the preseason may not be the fitness level of the injured player at the time of injury. Another limitation of our study was that data collection in terms of exposure time in the match was based on the best estimation of attendance of players in a match that may lead to bias.

4.6 CONCLUSION

The current study provides the information about incidence and nature of injuries in semi-professional and amateur rugby 15s players represented at the community level. Similar to the results that have been previously reported in epidemiological studies for different levels of rugby union, lower limb, ligament injuries and tackle were the most common site, type, and mechanism of injury. The results of our investigation suggest that Y balance test can be used as a predictive mean to identify amateur players at risk to severe injuries. This test helps to distinguish players with deficits and it may be feasible to modify these deficits by a neuromuscular preseason program before involving in the competitions. Insights into the injury characteristics at the community level also help to optimize the first aid provision and to promote injury prevention programs at this play level of rugby. Management of injury risk for rugby union can be included targeted prevention programs for the heads, shoulders, and knees that sustained more severe injuries as well as improvement in contact skills especially tackle.

CHAPTER 5

GENERAL DISCUSSION

The sport of rugby involves players in frequent bouts of high-intensity movement and collision such as running, tackling, rucking, mauling (Roberts *et al.*, 2008). As a consequence, rugby has a relatively higher reported injury incidence compared with other team sports such as soccer, hockey, and cricket (Nicholl *et al.*, 1995). In order to prevent injuries, recognition of risk factors of injury is the fundamental step in the prevention programs (Van Mechelen *et al.*, 1992) particularly those that are modifiable. Although some risk factors in terms of physical fitness has been identified previously in rugby union or similar sports such as rugby league and Australian rules football (Gabbett & Domrow, 2005; Gabbett *et al.*, 2012b; Freckleton *et al.*, 2013; Tee *et al.*, 2016), the results could not be generalized to rugby union with different format of games and level of competition. For instance, it has been reported that rugby-7s games have a higher incidence and greater injury severity when compared with the 15s games (Fuller *et al.*, 2010c; Fuller *et al.*, 2015). Studies had also indicated that injury rate increases with the increase of competition level (Brooks *et al.*, 2005a; Roberts *et al.*, 2013). Further, this study differs from other previous studies as only severe injuries were considered for analysis of risk factors instead of all injuries.

The present study aimed to determine injury incidence and identify risk factors for severe injuries in rugby union players with different competition levels and format of play. In order to achieve this, two studies were conducted covering different formats of playing as well as different competition level: university rugby-7s (amateur players) and community level rugby-15s (amateur and semi-professional players). Figure 5.1 shows the key findings of this study. The findings from our study indicated that some physical fitness tests could predict severe injuries at the amateur level of rugby union.

For rugby-7s, 40 m speed test as well as Illinois agility test, and in rugby-15s, Y balance test were identified as effective tests to predict severe injuries. Rugby-7s players with less agility and slow speed were 2 or 3.5-fold at higher risk of severe injuries. On the other hand, our findings of rugby-15s amateur players demonstrated that poorer balance ability was significant risk factor for severe injuries. These results can be justified based on the playing format, as the physical demands in the rugby-7s are greater than 15s, with many high-intensity sprints, rapid acceleration, deceleration and change of direction (Ross *et al.*, 2014). Therefore, speed and agility are crucial physical components in rugby-7s where fewer players (7 *vs*. 15) have to cover the same size ground as in rugby-15s (Ross *et al.*, 2014). These findings highlight the importance of speed and agility training to increase performance and reduce the incidence of severe injuries. The improvement of these functions helps players to position themselves quickly and properly before the contact skills. With the greater field for the Sevens players to cover, it would appear tackles and rucks would happen less commonly in rugby-7s than in rugby-15s (Ross *et al.*, 2014). Hence, the importance of dynamic balance is highlighted for rugby-15s players during dynamic activities where they need to stay on their feet during a ruck or when tackled and perform a multi-directional running task such as side steps. Our finding was consistent with a previous study (Jaco Ras & Puckree, 2014) that showed a significant inverse correlation between dynamic balance (using Biosway balance device) and injury incidence in rugby players. In the current study, shorter reach distance less than 593.1 cm and 597.9 cm for females and males, respectively, during Y balance performance was associated with 4.4 times greater risk of severe injuries. Players with reduced performance may be improved through the specific postural stability training program before entering into competition (Coughlan *et al.*, 2014b). Findings in our study also suggest that development of technical components such as tackle, ruck, scrum and other isolated skills may help to reduce the risk of severe injuries. Our study however could not identify any significant predictors for severe injuries in semi-professional rugby-15s players. A possible explanation is that semi-professional players are more experienced players than amateur players and their tackling skills are much better. Indeed, it has been suggested that tackling techniques improve in more experienced players (Hendricks *et al.*, 2012); Moreover, we noticed that the semi-professional players took part in more structured training sessions and conditioning programs than the amateur players. This might help them to apply better tactic and technique during competition and decrease the chance of severe injuries for them. Further investigation is needed to study other possible reasons such as psychological features in these players.

Considering other results of our study, the risk of injury also identified to be almost eight times higher for female rugby-7s players compared to males. Our finding was in agreement with another study (Ma *et al.*, 2016). Nonetheless, we take note that of the small sample size of females in our study, and further investigations are needed to further substantiate our findings. In connection with the amateur rugby-15s players, greater body weight than 58.9 kg for a female and 84.4 kg for a male was identified as a significant risk factor for severe injuries. The possible reason has been reported that greater body weight resulted in greater impact force during a contact that leads to increase the risk of severe injuries (Gabbett *et al.*, 2012b; Archbold *et al.*, 2015). Modifying the load of matches for this group of players is suggested; with decreasing the exposure such that they are less exposed to serious risks. On the other hand, the body weight effect was not shown in semi-professional players. This highlights the importance of skill that had been developed in the semi-professional players.

The injury incidence of our amateur rugby-7s players (59.3/1000 player hours) was similar to the injury rate of a group amateur players during a rugby-7s tournament series season (55.4/1000 player hours) (Lopez *et al.*, 2012). For the rugby-15s players, the results obtained at both amateur (114.7/1000 player hours) and semi-professional levels (89.4 /1000 player hours) were higher than that reported for amateur rugby-15s ranged between 16.6-52.3/1000 player hours (Takemura *et al.*, 2009; Roberts *et al.*, 2013; Swain *et al.*, 2016) and for semi-professional rugby-15s ranged between 21.7-54.1/1000 player hours (Schneiders *et al.*, 2009; Roberts *et al.*, 2013; Smith *et al.*, 2014). However, comparison among studies is difficult since the injury definition and study period are markedly different.

In our amateur rugby-7s players, the injury incidence of severe injury was 22.2/1000 player hours, in amateur rugby-15s players it was 14.7/1000 player hours, and in semi-professional rugby-15s players, it was 12.8/1000 player hours. The results demonstrated that amateur players, especially in the context of rugby-7s, sustained more severe injuries than semi-professional players. The higher incidence of severe injuries for professional rugby-7s compared with rugby-15s players had been reported previously (49 *vs*. 15.1/1000 player hours) (Fuller *et al.*, 2010c). The fast nature of rugby-7s game increases the probability of more severe injuries during tackle and other contact phases of play. This is in agreement with the greater incidence of severe injuries observed in our rugby-7s players. Nonetheless, it has to take note that the incidence of severe injuries is comparable to different levels of players in the current study as our results showed no significant difference for incidence of severe injuries between amateur-7s *vs*. amateur 15s players; and amateur 7s *vs*. semi-professional 15s players.

The findings of our two studies had similarity in some aspects; the most frequently reported injuries occurred in the lower limbs. Ligamentous injuries of the lower limb at the knee and ankle are the most common type of injuries. This is also in agreement with the findings reported for 7s players at the amateur level and 15s players at the amateur and semi-professional levels (Schneiders *et al.*, 2009; Takemura *et al.*, 2009; Ma *et al.*, 2016). The greatest proportion of injuries located on the upper limb was ligamentous injuries at the shoulder regions. Being tackled and tackling were the most common mechanism of the injuries at the heads and shoulders. This is in agreement with other investigations (Peck *et al.*, 2013). Amateur rugby-7s players frequently sustained ankle injuries while rugby-15s players for both levels of amateur and semi-professional commonly sustained head/face injuries. This can be explained by the nature of playing as rugby-7s play led to more running, cutting, and turning movements, which described the higher proportion of ankle and knee injuries (Fuller *et al.*, 2008). Indeed, the injury incidence of knee and ankle for rugby-7s players were twice those reported for rugby-15s players (Fuller *et al.*, 2010c). While rugby-15s contain more tackle than rugby-7s (Ross *et al.*, 2014), then head/face injuries were the most common injury. For severe injuries, ligamentous knee injury was the most common injury in our study and resulted in the greatest absent days. Considering tackle is the common mechanism for injuries in our study which is similar to other studies in rugby union-7s and 15s (Schneiders *et al.*, 2009; Ma *et al.*, 2016; Swain *et al.*, 2016), there is a necessity to study injury mechanisms of tackles in order to reduce the associated risk.

Our findings showed that over 50% of injuries at community rugby-15s, both amateur and semi-professional levels were associated with increased severity. In particular, at the amateur level, multiple injuries were significantly associated with increased severity with the proportion of 85%. This cannot be taken lightly and highlighted the role of full recovery before returning to rugby activity to decrease the chances of subsequent injuries.

Most of the severe injuries happened in the early part of the season. For amateur rugby-7s players, most of the severe injuries occurred in the first 21.8 hours (training + match) of the season and for amateur rugby-15s and semi-professional rugby-15s players happened in the first 7.5 hours (first six matches) and 8.3 hours (first seven matches) of the match exposure respectively. The transition from off season to the high volume of rugby activity either training or match without sufficient preparation at the early season can cause injuries. Also according to survival effect, those players predisposed to injury sustained an injury earlier, so their match exposure would be decreased for further injury (Roberts *et al.*, 2013). As a result, fewer severe injuries were seen when the season progresses. This result highlighted the importance of a proper preparation to adapt the physical fitness of players for the high load of activities at the beginning of the season. In addition, prevention strategies should be focused on monitoring players early in the season in order to minimize injuries. The findings from this study provide a further contribution to our understanding of risk factors of severe injuries in rugby union and have significant implications for future injury prevention strategies and research.

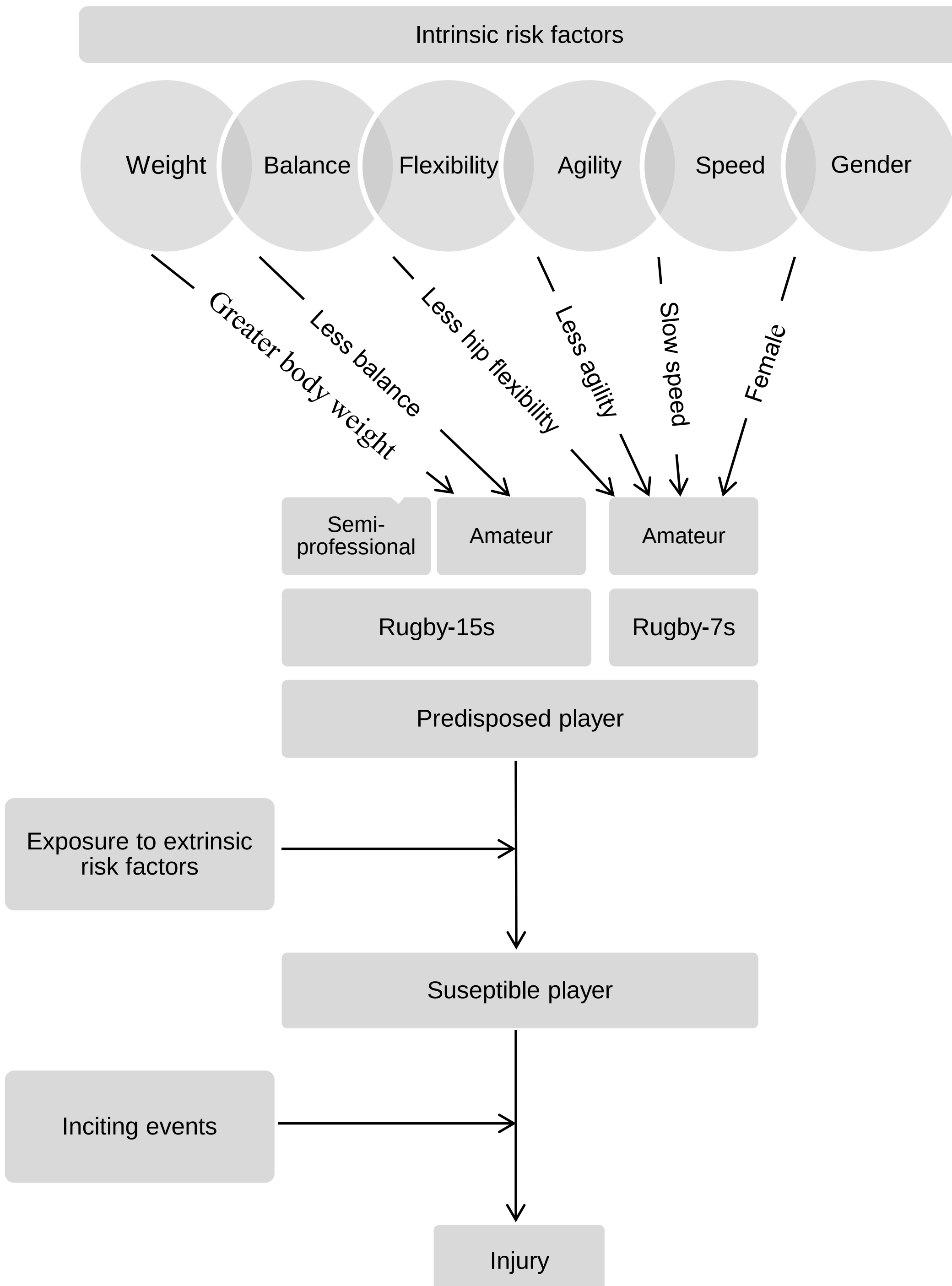

Figure 5.1 Risk factors leading to injury (adopted from Bahr & Krosshaug ,2005)

CHAPTER 6

CONCLUSION

6.1 KEY FINDINGS

The main findings from the present study of identifying risk factors for severe injuries in rugby players were:

1. For amateur rugby-7 players, the overall injury incidence during training and match play was 3.31 and 59.3 injuries per 1000 player hours. Match injuries led to 25.5 missed days, while training-related injuries led to 8.62 missed days. Severe injuries resulted in an average of 51.3 d time loss. The incidence of severe injuries for match and training were 22.2 and 0.66 per 1000 player hours, respectively.
2. For rugby-15s players, the overall injury incidence for the match was 89.4 and 114.7 injuries per 1000 player hours for semi-professional and amateur players. The mean time loss for semi-professional players was 10.1 d and 14.8 d for amateur players. Severe injuries resulted 45.8 d time loss for semi-professional players and 72.2 d for amateur players. The incidence of severe injuries for semi-professional and amateur was 12.8 and 14.7 injuries per 1000 player hours.
3. Regarding risk factors to severe injuries, female gender, slower speed, and decreased agility are predictors for severe rugby-related injuries in amateur rugby-7s players. Females were about eight times at higher risk of serious injuries than males. The less agile players, as reflected in Illinois agility test, had a 2-fold increased risk and slower players as assessed by 40 m speed test had a 3.5-fold increased risk for severe injuries. There was also a small association between tightness of the hip flexors with injury risk.
4. For semi-professional rugby-15s players, there was no significant predictor for severe injuries while weight and balance were identified as significant predictors for

severe injuries for amateur players. Body weight greater than 58.9 kg in females and 84.4 kg in males resulted in a 6.8-fold increased risk for severe injuries. Dynamic balance ability less than 593.1 cm in females and 597.9 cm in males had a 4.4-fold greater risk for severe injuries.

5. In the context of rugby-15s, over 50% of injuries associated with increased severity and in amateur level this proportion significantly was higher than that for injuries with no increased severity.
6. In the context of rugby-15s, there was significant difference between the multiple injuries with increased severity in subsequent injuries compared with those multiple injuries without increased severity for amateur players but not for semi-professional players.
7. Most severe injuries occurred at the early part of the rugby season. For amateur rugby-7s, these injuries happened at the first 21.8 hours of rugby activity, and for rugby-15s, it occurred at the first 8.3 hours and 7.5 hours of the match exposure time for semi-professional and amateur players respectively.
8. The most frequently reported injuries occurred in the lower limbs in both formats of play for rugby union. Injuries most frequently occurred at the knee and ankle region, with ligamentous injuries as the most common type. Shoulder ligamentous injuries accounted for the most common injuries in the upper limb. Being tackled and tackling were the most common mechanisms of injuries. In terms of the most common injuries, amateur rugby-7s players frequently sustained ankle injuries while rugby-15s players at both levels of amateur and semi-professional sustained head/face injuries, ligamentous knee injuries resulted in the greatest missed days.

6.2 ORIGINAL CONTRIBUTION TO KNOWLEDGE

'Original contribution to knowledge' has been defined as "the potential to do at least one of the following: afford new insights into little-understood phenomena, uncover new facts or principles, challenge existing truths or assumptions, suggest relationships that were previously unrecognized, or suggest new interpretations of known facts that can alter man's perception of the world around him" (Madsen, 1992). To that purpose, this study presents an original and notable contribution to the knowledge by:

1. Providing the first investigation of the influence of physical fitness parameters on the risk of severe injuries (>28 d time loss) in rugby union players in different format and level of play.
2. Highlighting the importance of speed and agility for amateur rugby-7s players as predictive risk factors for severe injuries.
3. Identifying the importance of dynamic balance for amateur rugby-15s players as predictive risk factors for severe injuries.
4. Determining the pattern of multiple injuries with increasing severity in rugby-15s players.

6.3 LIMITATIONS OF STUDY

The physical test results were collected preseason and the players' fitness may have changed throughout the playing season and therefore, may not represent the fitness level of the injured player at the time of injury. Another limitation of the study was that the exposure time is based on the best estimation of attendance of players in a match or training that may lead to bias. Furthermore, some players were involved in training outside university or club which may lead to underestimation of exposure time. Areas for further study include injury surveillance throughout consecutive seasons with a larger sample size. The number of females in rugby-7s study was much lower than those of males which might have affected results.

6.4 FUTURE DIRECTIONS

Prospective studies with the focus on risk factors of injury are important for player specific preventative strategies. These studies should be encouraged within different levels of each format of rugby union over multiple seasons to ensure consistency with existing findings. Our recommendation is to investigate other fitness tests to reach to a battery of effective tests in order to predict injuries. Future studies also need to be based on analysis of injury through individual monitoring to better identify risk factors. This information can help to set up more appropriate individualized rugby activity load prescription.

Appendix I

Study	Subjects	Incidence rate	Significant risk factors (95% CI)
Archbold *et al.* (2015) Over a season	Youth Rugby union	29.06/1000 match hours	• Heavier weight: > 77 kg (Adjusted HR = 1.32; 1.04-1.69) • Higher age: >16.9 years (Adjusted HR = 1.45; 1.14-1.83) • Undertaking regular strength training (AHR = 1.65; 1.11-2.46) • Playing representative rugby (AHR = 1.42; 1.06-1.90) • Wearing mouth guard (Adjusted HR = 0.70; 0.54-0.92) • 6. Playing for a lower ranked team (AHR = 0.67; 0.49- 0.90)
Bird *et al.*, (1998) Over a season	Secondary school + club Rugby union	72/100 players	• Gender : males had a higher rate of injury than females (10.9 vs. 6.1/100 player games, p < 0.001
Bourne *et al.*, (2015) Over a season	Elite+ sub-elite + youth Rugby union	20 injured players with at least one hamstring injury	• Previous injury (Relative risk [RR] = 4.1; 1.9-8.9) • Limb imbalance in eccentric knee flexor strength of > 15% (RR = 2.4; 1.1-5.5) and > 20% (RR = 3.4; 1.5-7.6)
Brooks *et al.*, (2005a) Over two seasons	Professional Rugby union	91 /1000 player hours	• Playing position: backs sustained higher incidence of non-contact injuries, incidence of tackled injuries was higher for backs and ruck/maul injuries was higher for forwards • Type of competition: major club competitions had higher injury incidence than friendly competitions • Time of season: pre-season injury incidence was < in-season (67vs.98/1000 player hours)

Study	Subjects	Incidence rate	Significant risk factors (95% CI)
Brooks *et al.*, (2006) Over two seasons	Professional Rugby union	0.27/1000 player training hours 5.6/ 1000 player match hours	• Playing position: backs sustained more hamstring injuries during match than forwards (8.6 vs. 3/1000 player hours) • High volumes of training: > 12.5 hours per week
Chalmers *et al.*, (2012) Over a season	Amateur Rugby union	9.8/100 player games	• Increasing age • Pacific Island ethnicity (IRR = 1.48; 1.03-2.13) • ≥ 40 hour strenuous physical activity a week (IRR = 1.54; 1.11-2.15) • Playing while injured (IRR = 1.46; 1.20-1.79) • Hard ground condition (IRR = 1.50, 1.13-2.00) • Foul play (IRR = 1.87; 1.54-2.27) • Use of headgear (IRR = 1.23; 1.00-1.50)
Fuller *et al.*, (2007a) Over two seasons	Professional Rugby union	53.8/1000 player hours	• Play position: more forwards injured in ruck/maul and more backs injured during tackle
Fuller *et al.*, (2013) Over seven weeks	Professional Rugby union	89.1/1000 player match hours 2.2/1000 player training hours	• Time of match: higher incidence of injury for second half of the match • Playing position: forward sustained more recurrent injuries than backs during training
Gabbett & Domrow, (2005) Over four years	Semi-professional Rugby league	55.4/1000 playing hours	• Playing experience < 10 years (OR = 0.22; 0.1-0.8) • Low speed (10-m, OR = 10.28; 1.40-75.67) and (40-m, OR = 9.93; 1.30-75.62) • Heavier weight (OR = 0.23; 0.06-0.93)

Study	Subjects	Incidence rate	Significant risk factors (95% CI)
Gabbett *et al.*, (2012b) Over three seasons	Professional Rugby league	92.5/1000 hours	• Greater body mass (HR = 2.6; 1.2-5.7) • Faster players (40 m test, HR = 2.1; 1.0-4.2) • Poor prolonged high-intensity intermittent running ability (8 × 12 s sprint-shuttle test, HR = 2.9; 1.7–5.0) • Poor upper-body strength (chin-up test, HR = 2.2; 1.3-3.7)
Haseler *et al.*, (2010) Over a season	Youth Rugby union	24/1000 player hours	• Higher numbers of moderate (20.6/1000 player hours, p < 0.005) and severe (9.5/1000 player hours, p < 0.05) injuries occurred in the U16–U17 age groups than younger age groups (U9–U10) with only minor injuries
Holtzhausen *et al.*, (2006) Over a season	Professional Rugby union	55.4/1000 player game hours 4.3/1000 player training hours	• Time of match: first quarter of much had the lowest injury rate (p = 0.000003) • Time of the season: preseason training was responsible for 38% of training injuries, pre-competition preparatory matches had higher injury incidence
Lee *et al.*, (2001) Over 16 weeks	Professional + amateur Rugby union	675 injury	• Higher age: > 16 years (OR = 1.98; 1.09-3.60) • Previous injury (OR = 1.83; 1.34-2.50)
Lopez *et al.*, (2012) 4 amateur 1-day tournaments	Amateur Rugby 7s	55.4/1000 playing hours	• Gender: higher rate of injury for male (RR= 7.5; 2.7-20.7)

Study	Subjects	Incidence rate	Significant risk factors (95% CI)
McDonough & Funk, (2014) Over a season	Professional + semi-professional Rugby league	11 shoulder injuries	• Internal range of motion (IR) of shoulder was predictor for injury (OR = 0.89)
McIntosh *et al*., (2010a) Over two seasons	Youth Rugby union	19.2/1000 player hours	• Higher age had greater injury rate • Position: significant differences in the rates of missed game injuries in terms of player position with greatest rate in inside backs
McIntosh *et al*., (2010b) Over five years	Professional + < 15 years + 18 years + 20 years Rugby union	66 injuries	• Age: players < 15 years sustained lower risk of tackle injuries than professional players (OR = 0.25; 0.08-0.93).
McManus & Cross, (2004) Over 26 weeks	Youth Rugby union	13.26/1000 player hours	• Time of the season: 73% of severe injuries happened in the first month of the season and (x^2 = 36.51; p = 0.000) • Playing position: there was association between playing position and severity of injuries, lock, center and halfback positions sustained more severe injuries (x2 = 67.49; p = 0.008) • Phase of play: 45% of injuries for backs and 80% of injuries for forwards happened during tackle (x^2 = 6.03; p = 0.014)
Palmer-Green *et al*., (2013) Over two seasons	Youth rugby academy + school Rugby union	Academy: 47/1000 player hours School: 35/1000 player hours	• Playing level: academic players had higher overall injury incidence compared with school players, ligament injuries was higher for academic players (24 vs. 14/1000 player hours)

Study	Subjects	Incidence rate	Significant risk factors (95% CI)
Peck *et al.*, (2013) Over five years	Collegiate Rugby union	Female:200 Male:459 injury	• Gender : the overall incidence rate for injury was 30% higher in male than female (IRR = 1.30, 1.09-1.54)
Quarrie *et al.*, (2001) Over a season	School + club Rugby union	Under 19: 47/1000 hours Under 21: 80/1000 hours Senior B: 81/1000 hours Senior A: 106/1000 hours	• Level of play (RR = 2.50; 1.67-3.74) • Previous injury (RR = 2.41; 1.34-4.32) • Playing position: midfield backs (RR = 2.55; 1.29-5.04) • Cigarette smoking status: Current smoker (RR = 2.11; 1.28-3.47) • Body mass index > 26.5 $kg.m^{-2}$ (RR = 2.02; 1.22-3.34) • Body mass > 81 kg (RR = 1.77; 1.09 to 2.86) • Push-ups: n = 20-23 rep (RR = 4.42; 1.85-10.53) • > 39 hour strenuous physical activity a week (RR = 3.71; 1.58-8.72) • Higher years of rugby experience: 4-5 years (RR = 0.42; 0.21-0.87)
Roberts *et al.*, (2013) Over three seasons	Semi-professional + amateur + recreational Rugby union	Semi-professional: 21.7 Amateur: 16.6 Recreational: 14.2 per 1000 player hours	• Playing position: thigh injuries significantly was more in backs and head/neck injuries was more in forwards • Playing level: semi-professional players sustained higher injury incident than lower levels

Study	Subjects	Incidence rate	Significant risk factors (95% CI)
Sankey *et al.*, (2008) Over two seasons	Professional Rugby union	226 ankle injuries	• Time of the season: the incidence rate of training injury during preseason was higher than in-season (0.43 vs. 0.16/1000 player hours) • Playing position: the incidence rate of training injury was higher in forwards than in backs (0.37 vs. 0.19/1000 player hours)
Tee *et al*., (2016) Over 6 months	Professional Rugby union	26 injuries	• Composite FMS score was lower in injured players and could predict injury(OR = 5.2; 2.0-14.0) • Combination of some tests: In-line lung + Deep squat (OR = 6.5; 0.8-54) Active straight leg raise + In-line lung (OR = 4.3; 0.9-21) In-line lung + Deep squat + Active straight leg raise (OR = 5.5; CI 1.1-27)
Yard & Comstock (2006) Over 26 years	All rugby players Over 26 years	6000 to 13000 injuries per year	• Gender & age: Injured male aged 23.3 ± 5.7 years were significantly older than injured females aged 21.2 ± 4.7 years ($p < 0.001$) • Younger age < 18 years more likely to be diagnosed with concussion

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

The Hong Kong Polytechnic University
Department of Rehabilitation Sciences

Informed Consent Form

Project title: **"Identifying risk factors for severe injuries in rugby players"**

Investigators: Ella Yeung, Simon Yeung, Nathan Stewart (supervisors)
Rezvan Mirsafaei Rizi (PhD student)

I, ______________________________, have been explained the details of this study. I voluntarily consent to participate in this study. I understand that I can withdraw from this study at any time without giving reasons, and my withdrawal will not lead to any punishment or prejudice against me. I am aware of any potential risk in joining this study. I also understand that my personal information will not be disclosed to people who are not related to this study and my name or photograph will not appear on any publications resulted from this study.

I can contact the chief investigator, Dr. Ella Yeung at telephone 2766 6748 for any questions about this study. If I have complaints related to the investigator(s), I can contact Ms Gloria Man, secretary of Departmental Research Committee, at 2766 4394. I know I will be given a signed copy of this consent form.

Signature (subject): Date:

Signature (witness): Date:

Hung Hom Kowloon Hong Kong
Tel (852) 2766 5111
Fax (852) 27843374
Email polyu@polyu.edu.hk
Website www.polyu.edu.hk

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

To	Yeung Wai Ella (Department of Rehabilitation Sciences)		
From	TSANG Wing Hong Hector, Chair, Departmental Research Committee		
Email	rshtsang@	Date	13-Sep-2014

Application for Ethical Review for Teaching/Research Involving Human Subjects

I write to inform you that approval has been given to your application for human subjects ethics review of the following project for a period from 15-Sep-2014 to 31-Dec-2017:

Project Title: Injury Prevention in Tertiary Rugby Players

Department: Department of Rehabilitation Sciences

Principal Investigator: Yeung Wai Ella

Reference Number: HSEARS20140828002

Please note that you will be held responsible for the ethical approval granted for the project and the ethical conduct of the personnel involved in the project. In the case of the Co-PI, if any, has also obtained ethical approval for the project, the Co-PI will also assume the responsibility in respect of the ethical approval (in relation to the areas of expertise of respective Co-PI in accordance with the stipulations given by the approving authority).

You are responsible for informing the Departmental Research Committee in advance of any changes in the proposal or procedures which may affect the validity of this ethical approval.

You will receive separate email notification should you be required to obtain fresh approval.

TSANG Wing Hong Hector

Chair

Departmental Research Committee

Rugby Injuries Survey

The purpose of this survey is to investigate the extent of rugby injuries during last season. The information gained will be important in developing effective measures in injury prevention. Please rest assured that the information collected will be handled in strict confidence and presented in aggregated form to protect your privacy.

Many thanks for your participation.
Dept. of Rehabilitation Sciences, Hong Kong Polytechnic University

A. Personal Details

*** 1. We kindly ask for your name and email for follow-up if need be.**

Name: [ ]

Email: [ ]

*** 2. Which team do you belong to?** [ ]

*** 3. What is your gender?** □ Male □ Female

*** 4. What is your age (in years)?** [ ]

*** 5. Your body build:** Weight (in kg): [ ] Height (in cm): [ ]

6. Which is your dominant LEG/ARM?
(Dominance is defined as the preferred use and better performance of that leg/arm as compared to the other side.)

Dominant LEG : □ Left □ Right

Dominant ARM : □ Left □ Right

B. Player's Experience

*** 8. For how long have you been playing rugby?**

□ Less than 1 year □ 2 years □ 4 years
□ 1 year □ 3 years □ 5 years
□ More than 5 years □ More than 10 years

*** 9. MATCH: how many matches have you played during last season?** No. of matches: [ ]

*** 10. TRAINING: how much training did you have during last season?**

No. of weeks of training: [ ]

No of sessions each week: [ ]

Duration each session (in minutes): [ ]

Comment (if any):...

*** 11. To what extent have you attended the training sessions in last season?**

- □ 100%
- □ 90%
- □ 80%
- □ 70%
- □ 60%
- □ 50%
- □ 40%
- □ 30%
- □ 20%
- □ 10%

C. Player Position

*** 12. What is your main playing position?**

- □ Loose-head prop
- □ Hooker
- □ Tight-head prop
- □ Number 4 lock
- □ Number 5 lock
- □ Blindside-flanker
- □ Open-side-flanker
- □ Number 8
- □ Scrum-half
- □ Fly-half
- □ Left-wing
- □ Inside-Centre
- □ Outside-Centre
- □ Right-wing
- □ Full-back

D. Rugby related injury

For the purpose of this study, RUGBY-RELATED INJURY is DEFINED as:

Any physical complaint sustained during a match or training session that prevented you from taking a full part in all training or match for 1 day or more following the day of injury, irrespective of whether match or training sessions were actually scheduled.

*** 13. Have you sustained a rugby-related injury last season?** □ Yes □ No

First injury

1-1. When did the injury occur? Month: [ ] Year: [ ]

2-1. This injury occurred during:

□ Pre-season (before regular match season)
□ Regular season (during regular match season)
□ Post season (after regular match season)

3-1.This injury was a:

□ New injury
□ Recurrence of rugby injury from this season
□ Recurrence of rugby injury from previous season
□ Complication of previous injury from rugby
□ Recurrence of other-sport injury
□ Complication of other-sport injury
□ Recurrence of non-sport injury

4-1. If this injury occurred during:

□ Match →
□ Warm up
□ 0-20 min
□ 21-40 min
□ 41-60 min
□ 61-80 min
□ Cool down

□ Training→
□ First half of training session
□ Second half of training session

Playing position during injury [ ]

5-1. If this injury was caused by:

□ Contact →
□ Tackled
□ Tackling
□ Ruck
□ Maul
□ Scrum
□ Collision - non-tackle
□ Other.....................

□ Non-contact →
□ Running
□ Changing direction
□ Jumping
□ Passing
□ Kicking
□ Twisting/turning
□ Other.....................

6-1. Specify the injured body part(s):

□ Head	□ Eye	□ Ear	□ Nose	□ Knee
□ Face	□ Chin	□ Jaw	□ Clavicle	□ Foot
□ Mouth/teeth	□ Neck/ cervical spine	□ Shoulder	□ Scapula	□ Knee cap
□ Upper arm	□ Elbow	□ Wrist	□ Hand	□ Toe(s)
□ Forearm	□ Thumb	□ Finger(s)	□ Ribs	□ Ankle
□ Upper back	□ Stomach	□ Pelvis	□ Sternum	□ Internal organs
□ Lower back	□ Upper leg (front)	□ Hip	□ Buttocks	□ Achilles tendon
□ Hamstring	□ Lower leg	□ Groin	□ Heel	
□ Other................				

7-1. Side of the body injured:

□ Left
□ Right
□ Both sides
□ Front
□ Back
□ Not applicable

8-1. Type of injury:

□ Stress fracture
□ Fracture
□ Joint dislocation
□ Ligament tears / strain
□ Muscle tears/strain
□ Tendon injury
□ Complete tendon rupture
□ Meniscus / cartilage injury
□ Muscle spasm
□ Nerve injury
□ Laceration
□ Cut / open wound
□ Dental injury
□ Other injury (please specify)……………………………….
□ Concussion injury
□ Bruise / hematoma
□ Head injury
□ Spinal injury
□ Pain / undiagnosed
□ Internal organ injury

9-1. Did your injury require?

□ Hospital admission
□ No treatment required
□ Health care attention
(by general practitioner, physiotherapist, orthopedic specialist, athletic trainer)
□ Self-treatment
□ Other injury (please specify)…………

10-1. The diagnosis given for your injury was:

11-1. How many days did this injury keep you from participating in training or competition?
(Please give best estimate)

No. of days:

12-1. At this stage, are you fully recovered from your injury?

□ Yes, 100%
□ 90%
□ 80%
□ 70%
□ 60%
□ 50%
□ 40%
□ 30%
□ 20%
□ 10%

13-1. Are you currently receiving treatment for this injury? □ Yes □ No

14-1. Do you anticipate any difficulties in normal training and competition due to this injury for this season (2015-16)?

□ Full participation without any problems
□ Full participation, but with problems
□ Reduced participation due to problems
□ Cannot participate due to problems

15-1.Beside this injury, do you have another rugby-related injury? □ Yes □ No

If your answer is "YES" please continue…

INJURY REPORT FORM

Team:

Full Name: [ ]

1. When did the injury occur? Day: [ ] Month: [ ] Year: [ ]

2. This injury was a:

□ New injury
□ Recurrence of rugby injury from this season
□ Recurrence of rugby injury from previous season
□ Recurrence of other-sport injury
□ Recurrence of non-sport injury
□ Complication of previous injury from rugby
□ Complication of other-sport injury

→ Date of previous injury: Month: [ ] Year: [ ]

→ Was player still being treated for the previous Injury? □ Yes □ No

3. If this injury occurred during:

□ Match →
□ Warm up
□ 0-20 min
□ 21-40 min
□ 41-60 min
□ 61-80 min
□ Cool down

□ Training→
□ First half of training session
□ Second half of training session

Injury occurred in:
□ Rugby skills
□ Conditioning weight session
□ Conditioning non-weight session
□ Other (please specify)…………

Playing position [ ]

4. If this injury was caused by:

□ Contact →
□ Tackled
□ Tackling
□ Collision - non-tackle
□ Ruck
□ Maul
□ Scrum
□ Other
(Please specify)………

□ Non-contact →
□ Running
□ Changing direction
□ Jumping
□ Passing
□ Kicking
□ Twisting/turning
□ Other
(Please specify)……..

If there is any other possible reason (Foul play, ground condition, fatigue, weather…)

…………………………………………………………

5. Side of the body injured:

□ Left
□ Right
□ Both sides
□ Front
□ Back
□ Not applicable

6. Specify the injured body part(s):

□ Head	□ Eye	□ Ear	□ Nose	□ Knee
□ Face	□ Chin	□ Jaw	□ Clavicle	□ Foot
□ Mouth/teeth	□ Neck/ cervical spine	□ Shoulder	□ Scapula	□ Knee cap
□ Upper arm	□ Elbow	□ Wrist	□ Hand	□ Toe(s)
□ Forearm	□ Thumb	□ Finger(s)	□ Ribs	□ Ankle
□ Upper back	□ Stomach	□ Pelvis	□ Sternum	□ Internal organs
□ Lower back	□ Upper leg (front)	□ Hip	□ Buttocks	□ Achilles tendon
□ Hamstring	□ Lower leg	□ Groin	□ Heel	□ Other………

7. Type of injury:

□ Stress fracture	□ Meniscus / cartilage injury	□ Concussion injury
□ Fracture	□ Muscle spasm	□ Bruise / hematoma
□ Joint dislocation	□ Nerve injury	□ Head injury
□ Ligament tears / strain	□ Laceration	□ Spinal injury
□ Muscle tears/strain	□ Cut / open wound	□ Pain / undiagnosed
□ Tendon injury	□ Dental injury	□ Internal organ injury
□ Complete tendon rupture	□ Other injury (please specify)………………………………	

8. Did your injury require?

□ Hospital admission	□ Self-treatment
□ No treatment required	□ Other injury (please specify)…………
□ Health care attention	

(by general practitioner, physiotherapist, orthopedic specialist, athletic trainer)

9. The diagnosis given for your injury was: [ ]

10. How many days did this injury keep you from participating in training or competition?
(Please give best estimate)

No. of days: [ ]

11. At this stage, are you fully recovered from your injury?

□ Yes, 100%	□ 70%	□ 40%	□ 10%
□ 90%	□ 60%	□ 30%	
□ 80%	□ 50%	□ 20%	

12. At this stage, do you anticipate any difficulties in normal training and competition due to this injury?

□ Full participation without any problems	□ Reduced participation due to problems
□ Full participation, but with problems	□ Cannot participate due to problems

Date: ________________________

Filled in by: ___________________

REFERENCES

Anderson A, Hoffman J, Johnson B, Simonson A, Urquhart L. Core strength testing: Developing normative data for three clinical tests. *St. Catherine University* 2014; Doctor of Physical Therapy Program.

Archbold H, Rankin A, Webb M, Nicholas R, Eames N, Wilson R, Henderson L, Heyes G, Bleakley C. RISUS study: Rugby injury surveillance in Ulster schools. *Br J Sports Med* 2015; 51:600–606.

Atkins SJ. Performance of the yo-yo intermittent recovery test by elite professional and semiprofessional rugby league players. *J Strength Cond Res* 2006; 20:222-225.

Austin D, Gabbett T, Jenkins D. The physical demands of super 14 rugby union. *J Sci Med Sport* 2011; 14:259-263.

Ayala F, de Baranda PS, Croix MDS, Santonja F. Reproducibility and criterion-related validity of the sit and reach test and toe touch test for estimating hamstring flexibility in recreationally active young adults. *Phys Ther Sport* 2012; 13:219-226.

Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test. *Sports Med* 2008; 38:37-51.

Barr MJ, Sheppard JM, Newton R. Sprinting kinematics of elite rugby players. *J Strength Cond Res* 2013; 21:14-20.

Bathgate A, Best JP, Craig G, Jamieson M. A prospective study of injuries to elite Australian rugby union players. *Br J Sports Med* 2002; 36:265-269.

Baumgartner TA, Oh S, Chung H, Hales D. Objectivity, reliability, and validity for a revised push-up test protocol. *Meas Phys Educ Exerc Sci* 2002; 6:225-242.

Beardmorea AL, Handcockb PJ, Rehrerb NJ. Return-to-play after injury: practices in New Zealand rugby union. *Phys Ther Sport* 2005; 6:24-30.

Bennell K, Talbot R, Wajswelner H, Techovanich W, Kelly D, Hall A. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion. *Aust J Physiother* 1998; 44:175-180.

Best JP, McIntosh AS, Savage TN. Rugby world cup 2003 injury surveillance project. *Br J Sports Med* 2005; 39:812-817.

Bird Y, Waller AE, Marshall SW, Alsop J, Chalmers D, Gerrard D. The New Zealand rugby injury and performance project: V. Epidemiology of a season of rugby injury. *Br J Sports Med* 1998; 32:319-325.

Biscombe T, Drewett P. *Rugby : Steps to success*, 2nd ed, Champaign, IL, Human Kinetics; 2010.

Bohu Y, Julia M, Bagate C, Peyrin J-C, Colonna J-P, Thoreux P, Pascal-Moussellard H. Declining incidence of catastrophic cervical spine injuries in French rugby 1996–2006. *Am J Sports Med* 2009; 37:319-323.

Bourne MN, Opar DA, Williams MD, Shield AJ. Eccentric knee flexor strength and risk of hamstring injuries in rugby union: a prospective study. *Am J Sports Med* 2015:2663-2670.

Braham R, Finch CF, Mclntosh A, McCrory P. Community level Australian football: a profile of injuries. *J Sci Med Sport* 2004; 7:96-105.

Brooks JH, Fuller CW, Kemp SP, Reddin DB. An assessment of training volume in professional rugby union and its impact on the incidence, severity, and nature of match and training injuries. *J Sports Sci* 2008; 26:863-873.

Brooks JHM. The epidemiology of injuries in professional rugby union. *University of Leicester* 2004; Ph.D Thesis.

Brooks JHM, Fuller CW, Kemp SPT, Reddin DB. Epidemiology of injuries in English professional rugby union: part 1 match injuries. *Br J Sports Med* 2005a; 39:757-766.

Brooks JHM, Fuller CW, Kemp SPT, Reddin DB. Epidemiology of injuries in English professional rugby union: part 2 training injuries. *Br J Sports Med* 2005b; 39:767-775.

Brooks JHM, Fuller CW, Kemp SPT, Reddin DB. Incidence, risk, and prevention of hamstring muscle injuries in professional rugby union. *Am J Sports Med* 2006; 34:1297-1306.

Brooks JHM, Fuller CW, Kemp SPT, Reddin DB. A prospective study of injuries and training amongst the England 2003 rugby world cup squad. *Br J Sports Med* 2005c; 39:288-293.

Brooks JHM, Kemp SPT. Injury-prevention priorities according to playing position in professional rugby union players. *Br J Sports Med* 2011; 45:765-775.

Brooks JHM, Kemp SPT. Recent trends in rugby union injuries. *Clin J Sport Med* 2008; 27:51-73.

Brown JC, Lambert MI, Verhagen E, Readhead C, Van Mechelen W, Viljoen W. The incidence of rugby-related catastrophic injuries (including cardiac events) in South Africa from 2008 to 2011: a cohort study. *BMJ open* 2013; 3:e002475.

Burns SA, Foresman E, Kraycsir SJ, Egan W, Glynn P, Mintken PE, Cleland JA. A treatment-based classification approach to examination and intervention of lumbar disorders. *Sports Health* 2011; 3:362-372.

Cahill N, Lamb K, Worsfold P, Headey R, Murray S. The movement characteristics of English premiership rugby union players. *J Sports Sci* 2013; 31:229-237.

Caine DJ, Maffulli N. *Epidemiology of pediatric sports injuries: Team sports*, Karger Medical and Scientific Publishers; 2005.

Calvisi V, Goderecci R, Necozione S. Rugby Injuries: Epidemiology and mechanism, in *Arthroscopy and Sport Injuries*. Volpi P ed, Springer, 2016.

Carlson BR, Carter JL, Patterson P, Petti K, Orfanos SM, Noffal GJ. Physique and motor performance characteristics of US national rugby players. *J Sports Sci* 1994; 12:403-412.

Chalmers DJ, Samaranayaka A, Gulliver P, McNoe B. Risk factors for injury in rugby union football in New Zealand: a cohort study. *Br J Sports Med* 2012; 46:95-102.

Chiwaridzo M, Ferguson GD, Smits-Engelsman BC. A systematic review protocol investigating tests for physical or physiological qualities and game-specific skills commonly used in rugby and related sports and their psychometric properties. *Syst. Rev* 2016; 5:122.

Collins CL, Micheli LJ, Yard EE, Comstock RD. Injuries sustained by high school rugby players in the United States, 2005-2006. *Arch Pediatr Adolesc Med* 2008; 162:49-54.

Comstock RD, Fields SK. The fair sex? Foul play among female rugby players. *J Sci Med Sport* 2005; 8:101-110.

Coughlan GF, Delahunt E, Caulfield BM, Forde C, Green BS. Normative adductor squeeze test values in elite junior rugby union players. *Clin J Sport Med* 2014a; 24:315-319.

Coughlan GF, Delahunt E, O'Sullivan E, Fullam K, Green BS, Caulfield BM. Star excursion balance test performance and application in elite junior rugby union players. *Phys Ther Sport* 2014b; 15:249-253.

Dallalana RJ, Brooks JH, Kemp SP, Williams AM. The epidemiology of knee injuries in English professional rugby union. *Am J Sports Med* 2007; 35:818-830.

Daneshvar DH, Baugh CM, Nowinski CJ, McKee AC, Stern RA, Cantu RC. Helmets and mouth guards: the role of personal equipment in preventing sport-related concussions. *Clin Sports Med* 2011; 30:145-163.

Darrall-Jones JD, Jones B, Till K. Anthropometric and physical profiles of English academy rugby union players. *J Strength Cond Res* 2015; 29:2086-2096.

Dawes J, Roozen M. *Developing agility and quickness*, Champaign, IL : Human Kinetics; 2012.

De Loës M. Exposure data. Why are they needed? *Sports Med* 1997; 24:172-175.

Delahunt E, Kennelly C, McEntee BL, Coughlan GF, Green BS. The thigh adductor squeeze test: 45 of hip flexion as the optimal test position for eliciting adductor muscle activity and maximum pressure values. *Man Ther* 2011; 16:476-480.

Dennis RJ, Finch CF, McIntosh AS, Elliott BC. Use of field-based tests to identify risk factors for injury to fast bowlers in cricket. *Br J Sports Med* 2008; 42:477-482.

Deprez D, Coutts AJ, Lenoir M, Fransen J, Pion J, Philippaerts R, Vaeyens R. Reliability and validity of the yo-yo intermittent recovery test level 1 in young soccer players. *J Sports Sci* 2014; 32:903-910.

Durandt J, Du Toit S, Borresen J, Hew-Butler T, Masimla H, Jakoet I, Lambert M. Fitness and body composition profiling of elite junior South African rugby players: original research article. *S Afr J Sports Med* 2006; 18:p. 38-45.

Duthie G, Pyne D, Hooper S. Applied physiology and game analysis of rugby union. *Sports Med* 2003; 33:973-991.

Edmondston SJ, Wallumrød ME, MacLéid F, Kvamme LS, Joebges S, Brabham GC. Reliability of isometric muscle endurance tests in subjects with postural neck pain. *J Manipulative Physiol Ther* 2008; 31:348-354.

Edwards C, Tod D, McGuigan M. Self-talk influences vertical jump performance and kinematics in male rugby union players. *J Sports Sci* 2008; 26:1459-1465.

Ellenbecker TS, Roetert EP, Piorkowski PA, Schulz DA. Glenohumeral joint internal and external rotation range of motion in elite junior tennis players. *J Orthop Sports Phys Ther* 1996; 24:336-341.

Fernández JJC, Aravena RE, Verdugo RL, Echeñique SC, Feito MO, Rex FS. Glenohumeral rotation range deficit in professional rugby players: a cross sectional study. *Rev Int Cienc Deporte* 2011; 7:39-47.

Fitzgerald D, Trakarnratanakul N, Smyth B, Caulfield B. Effects of a wobble board-based therapeutic exergaming system for balance training on dynamic postural stability and intrinsic motivation levels. *J Orthop Sports Phys Ther* 2010; 40:11-19.

Fitzgerald GK, Lephart SM, Hwang JH, Wainner MRS. Hop tests as predictors of dynamic knee stability. *J Orthop Sports Phys Ther* 2001; 31:588-597.

Fleiss J. *The design and analysis of clinical experiments*, Taylor & Francis; 1986.

Freckleton G, Cook J, Pizzari T. The predictive validity of a single leg bridge test for hamstring injuries in Australian rules football players. *Br J Sports Med* 2013; 48:713-717.

Fuller CW. Catastrophic injury in rugby union. *Sports Med* 2008; 38:975-986.

Fuller CW, Ashton T, Brooks JH, Cancea RJ, Hall J, Kemp SP. Injury risks associated with tackling in rugby union. *Br J Sports Med* 2010a; 44:159–167.

Fuller CW, Brooks JH, Cancea RJ, Hall J, Kemp SP. Contact events in rugby union and their propensity to cause injury. *Br J Sports Med* 2007a; 41:862-867.

Fuller CW, Brooks JH, Kemp SP. Spinal injuries in professional rugby union: a prospective cohort study. *Clin J Sport Med* 2007b; 17:10-16.

Fuller CW, Clarke L, Molloy MG. Risk of injury associated with rugby union played on artificial turf. *J Sports Sci* 2010b; 28:563-570.

Fuller CW, Laborde F, Leather R, Molloy MG. International rugby board rugby world cup 2007 injury surveillance study. *Br J Sports Med* 2008; 42:452-459.

Fuller CW, Molloy MG, Bagate C, Bahr R, Brooks JHM, Donson H, Kemp SPT, McCrory P, McIntosh AS, Meeuwisse WH, Quarrie KL, Raftery M, Wiley P. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. *Br J Sports Med* 2007c; 41:328.

Fuller CW, Sheerin K, Targett S. Rugby world cup 2011: International rugby board injury surveillance study. *Br J Sports Med* 2013; 47:1184-1191.

Fuller CW, Taylor A, Kemp SP, Raftery M. Rugby world cup 2015: World rugby injury surveillance study. *Br J Sports Med* 2017; 51:51-57.

Fuller CW, Taylor A, Molloy MG. Epidemiological study of injuries in international rugby Sevens. *Clin J Sport Med* 2010c; 20:179-184.

Fuller CW, Taylor A, Raftery M. Epidemiology of concussion in men's elite Rugby-7s (Sevens World Series) and Rugby-15s (Rugby World Cup, Junior World Championship and Rugby Trophy, Pacific Nations Cup and English Premiership). *Br J Sports Med* 2015; 49:478-483.

Fuller CW, Taylor AE, Raftery M. Should player fatigue be the focus of injury prevention strategies for international rugby Sevens tournaments? *Br J Sports Med* 2016; 50:682-687.

Fulton J, Wright K, Kelly M, Zebrosky B, Zanis M, Drvol C, Butler R. Injury risk is altered by previous injury: a systematic review of the literature and presentation of causative neuromuscular factors. *Int J Sports Phys Ther* 2014; 9:583-595.

Gabb N, Trewartha G, Kemp S, Stokes K. Epidemiology of injuries in a women's international rugby Sevens world cup squad. *Br J Sports Med* 2014; 48:596-597.

Gabbett T. A comparison of physiological and anthropometric characteristics among playing positions in junior rugby league players. *Br J Sports Med* 2005; 39:675-680.

Gabbett TJ. Influence of fatigue on tackling technique in rugby league players. *J Strength Cond Res* 2008; 22:625-632.

Gabbett TJ. Physiological and anthropometric characteristics of amateur rugby league players. *Br J Sports Med* 2000; 34:303-307.

Gabbett TJ. Reductions in pre-season training loads reduce training injury rates in rugby league players. *Br J Sports Med* 2004; 38:743-749.

Gabbett TJ. Severity and cost of injuries in amateur rugby league: a case study. *J Sport Sci* 2001; 19:341-347.

Gabbett TJ, Domrow N. Risk factors for injury in subelite rugby league players. *Am J Sports Med* 2005; 33:428-434.

Gabbett TJ, Jenkins DG, Abernethy B. Physical demands of professional rugby league training and competition using microtechnology. *J Sci Med Sport* 2012a; 15:80-86.

Gabbett TJ, Johns J, Riemann M. Performance changes following training in junior rugby league players. *J Strength Cond Res* 2008; 22:910-917.

Gabbett TJ, Ullah S, Finch CF. Identifying risk factors for contact injury in professional rugby league players–Application of a frailty model for recurrent injury. *J Sci Med Sport* 2012b; 15:496-504.

Gamble P. Physical preparation for elite-level rugby union football. *Strength Cond J* 2004; 26:10-23.

Garraway W, Lee A, Hutton S, Russell E, Macleod D. Impact of professionalism on injuries in rugby union. *Br J Sports Med* 2000; 34:348-351.

Garraway W, Macleod D. Epidemiology of rugby football injuries. *Lancet* 1995; 345:1485-1487.

Gerrard D, Waller AE, Bird Y. The New Zealand rugby injury and performance project: II. Previous injury experience of a rugby-playing cohort. *Br J Sports Med* 1994; 28:229-233.

Gianotti S, Hume PA, Hopkins W, Harawira J, Truman R. Interim evaluation of the effect of a new scrum law on neck and back injuries in rugby union. *Br J Sports Med* 2008; 42:427-430.

Glaister M, Hauck H, Abraham CS, Merry KL, Beaver D, Woods B, McInnes G. Familiarization, reliability, and comparability of a 40-m maximal shuttle run test. *J Sports Sci Med* 2009; 8:77-82.

Gribble PA, Hertel J. Considerations for normalizing measures of the star excursion balance test. *Meas Phys Educ Exerc Sci* 2003; 7:89-100.

Gwinn DE, Wilckens JH, McDevitt ER, Ross G, Kao T-C. The relative incidence of anterior cruciate ligament injury in men and women at the United States Naval Academy. *Am J Sports Med* 2000; 28:98-102.

Hachana Y, Chaabène H, Nabli MA, Attia A, Moualhi J, Farhat N, Elloumi M. Test-retest reliability, criterion-related validity, and minimal detectable change of the Illinois agility test in male team sport athletes. *J Strength Cond Res* 2013; 27:2752-2759.

Hägglund M, Waldén M, Ekstrand J. Previous injury as a risk factor for injury in elite football: a prospective study over two consecutive seasons. *Br J Sports Med* 2006; 40:767-772.

Hallet P. A reliability study examining the inter-and intra-observer reliability of the muscle capacity tests included in the ECB musculoskeletal screening protocol. *University of Nottingham* 2010; M.Sc. Dessertation.

Harvey D. Assessment of the flexibility of elite athletes using the modified Thomas test. *Br J Sports Med* 1998; 32:68-70.

Haseler CM, Carmont MR, England M. The epidemiology of injuries in English youth community rugby union. *Br J Sports Med* 2010; 44:1093-1099.

Headey J, Brooks JHM, Kemp SPT. The epidemiology of shoulder injuries in English professional rugby union. *Am J Sports Med* 2007; 35:1537-1543.

Hendricks S, Jordaan E, Lambert M. Attitude and behaviour of junior rugby union players towards tackling during training and match play. *Safety Sci* 2012; 50:266–284.

Hene N, Bassett S, Andrews B. Physical fitness profiles of elite women's rugby union players. *Afr J Phys Health Educ Recr Dance* 2011:1-8.

Hermanus FJ, Draper CE, Noakes TD. Spinal cord injuries in South African rugby union (1980-2007). *S Afr Med J* 2010; 100:230-234.

Hertel J, Braham RA, Hale SA, Olmsted-Kramer LC. Simplifying the star excursion balance test: analyses of subjects with and without chronic ankle instability. *J Orthop Sports Phys Ther* 2006; 36:131-137.

Higgins TR, Climstein M, Cameron M. Evaluation of hydrotherapy, using passive tests and power tests, for recovery across a cyclic week of competitive rugby union. *J Strength Cond Res* 2013; 27:954-965.

HKRU. About us. http://www.hkrugby.com/about/about-us. Accessed 2 November 2016a.

HKRU. Tertiary. http://www.hkrugby.com/domestic/tertiary. Accessed 7 November 2016b.

Hodgson L, Hignett T, Edwards K. Normative adductor squeeze tests scores in rugby. *Phys Ther Sport* 2015; 16:93-97.

Holtzhausen LJ, Schwellnus MP, Jakoet I, Pretorius A. The incidence and nature of injuries in South African rugby players in the rugby super 12 competition. *S Afr Med J* 2006; 96:1260-1265.

Homoud MNA. Relationship between Illinoise agility test and reaction time in male athletes. *Swed J Sci Res* 2015; 2:28-33.

Hopkins WG, Marshall SW, Quarrie KL, Hume PA. Risk factors and risk statistics for sports injuries. *Clin J Sport Med* 2007; 17:208-210.

Jaco Ras M, Puckree T. Injury incidence and balance in rugby players. *Pak J Med Sci* 2014; 30:1346.

Jarvis S, Sullivan LO, Davies B, Wiltshire H, Baker JS. Interrelationships between measured running intensities and agility performance in subelite rugby union players. *Res Sports Med* 2009; 17:217-230.

Johnson BL, Nelson JK. *Practical measurements for evaluation in physical education,* 3rd ed, Minneapolis : Burgess Pub. Co; 1979.

Johnston LH, Carroll D. The context of emotional responses to athletic injury: a qualitative analysis. *J Sport Rehabil* 1998; 7:206-220.

Junge A, Cheung K, Edwards T, Dvorak J. Injuries in youth amateur soccer and rugby players-comparison of incidence and characteristics. *Br J Sports Med* 2004; 38:168-172.

Juul T, Langberg H, Enoch F, Søgaard K. The intra-and inter-rater reliability of five clinical muscle performance tests in patients with and without neck pain. *BMC Musculoskelet Disord* 2013; 14:339.

Kaplan KM, Goodwillie A, Strauss EJ, Rosen JE. Rugby injuries: a review of concepts and current literature. *Bull Hosp Jt Dis* 2008; 66:86-93.

Kaux J-F, Julia M, Delvaux F, Croisier J-L, Forthomme B, Monnot D, Chupin M, Crielaard J-M, Goff CL, Durez P. Epidemiological review of injuries in rugby union. *Sports* 2015; 3:21-29.

Kemp SP, Hudson Z, Brooks JH, Fuller CW. The epidemiology of head injuries in English professional rugby union. *Clin J Sport Med* 2008; 18:227-234.

Kennedy MD, Fischer R, Fairbanks K, Lefaivre L, Vickery L, Molzan J, Parent E. Can pre-season fitness measures predict time to injury in varsity athletes?: a retrospective case control study. *Sports Med Arthrosc Rehabil Ther Technol* 2012; 4:26.

Kerr HA, Curtis C, Micheli LJ, Kocher MS, Zurakowski D, Kemp S, Brooks J. Collegiate rugby union injury patterns in New England: a prospective cohort study. *Br J Sports Med* 2008; 42:595-603.

Keys A, Fidanza F, Karvonen MJ, Kimura N, Taylor HL. Indices of relative weight and obesity. *J Chronic Dis* 1972; 25:329-343.

Kinzey SJ, Armstrong CW. The reliability of the star-excursion test in assessing dynamic balance. *J Orthop Sports Phys Ther* 1998; 27:356-360.

Krivickas LS, Feinberg JH. Lower extremity injuries in college athletes: relation between ligamentous laxity and lower extremity muscle tightness. *Arch Phys Med Rehabil* 1996; 77:1139-1143.

Kumar S. Theories of musculoskeletal injury causation. *Ergonomics* 2001; 44:17-47.

Kuster D, Gibson A, Abboud R, Drew T. Mechanisms of cervical spine injury in rugby union: a systematic review of the literature. *Br J Sports Med* 2012; 46:550-554.

Lark DS. Better rugby coaching stretch away from injury. http://www.betterrugbycoaching.com/BRC/BRC_335.asp. Accessed 27 November 2015.

Lavallée L, Flint F. The relationship of stress, competitive anxiety, mood state, and social support to athletic injury. *J Athl Train* 1996; 31:296-299.

Lee AJ, Garraway W, Arneil D. Influence of preseason training, fitness, and existing injury on subsequent rugby injury. *Br J Sports Med* 2001; 35:412-417.

Lee AJ, Garraway WM. Epidemiological comparison of injuries in school and senior club rugby. *Br J Sports Med* 1996; 30:213-217.

Lee AJ, Garraway WM. The influence of environmental factors on rugby football injuries. *J Sports Sci* 2000; 18:91-95.

Leetun DT, Ireland ML, Willson JD, Ballantyne BT, Davis IM. Core stability measures as risk factors for lower extremity injury in athletes. *Med Sci Sports Exerc* 2004; 36:926-934.

Lin JJ, Yang JL. Reliability and validity of shoulder tightness measurement in patients with stiff shoulders. *Man Ther* 2006; 11:146-152.

Lopez V, Galano GJ, Black CM, Gupta AT, James DE, Kelleher KM, Allen AA. Profile of an American amateur rugby union Sevens series. *Am J Sports Med* 2012; 40:179-184.

Ma R, Lopez Jr V, Weinstein MG, Chen JL, Black CM, Gupta AT, Harbst JD, Victoria C, Allen AA. Injury profile of American women rugby-7s. *Med Sci Sports Exerc* 2016; 48:1957-1966.

Madsen D. *Successful dissertations and theses: a guide to graduate student research from proposal to completion,* 2nd ed, San Francisco, Calif, Jossey-Bass; 1992.

Magee DJ. *Orthopedic physical assessment*, 6th ed, St. Louis, Missouri : Elsevier Saunders; 2014.

Malliaras P, Hogan A, Nawrocki A, Crossley K, Schache A. Hip flexibility and strength measures: reliability and association with athletic groin pain. *Br J Sports Med* 2009; 43:739-744.

Manske RC, Smith BS, Wyatt FB. Test-retest reliability of lower extremity functional tests after a closed kinetic chain isokinetic testing bout. *J Sports Rehabil* 2003; 12:119-132.

Maria van Gent M, Spamer EJ. Comparisons of positional groups in terms of anthropometric, rugby-specific skills, physical and motor components among u 13, u 16, u 18 and u 19 elite rugby players. *Kinesiology* 2005; 37:50-63.

Marshall B, Franklyn-Miller A, Moran K, King E, Richter C, Gore S, Strike S, Falvey É. Biomechanical symmetry in elite rugby union players during dynamic tasks: an investigation using discrete and continuous data analysis techniques. *BMC Sports Sci Med Rehabil* 2015; 7:13.

Marshall SW, Loomis DP, Waller AE, Chalmers DJ, Bird YN, Quarrie KL, Feehan M. Evaluation of protective equipment for prevention of injuries in rugby union. *Int J Epidemiol* 2005; 34:113-118.

Maud P. Physiological and anthropometric parameters that describe a rugby union team. *Br J Sports Med* 1983; 17:16-23.

McCrory P. Do mouthguards prevent concussion? *Br J Sports Med* 2001; 35:81-82.

McDonough A, Funk L. Can glenohumeral joint isokinetic strength and range of movement predict injury in professional rugby league. *Phys Ther Sport* 2014; 15:91-96.

McGill SM, Andersen JT, Horne AD. Predicting performance and injury resilience from movement quality and fitness scores in a basketball team over 2 years. *J Strength Cond Res* 2012; 26:1731-1739.

McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. *Arch Phys Med Rehabil* 1999; 80:941-944.

McIntosh AS, McCrory P, Finch CF, Wolfe R. Head, face and neck injury in youth rugby: incidence and risk factors. *Br J Sports Med* 2010a; 44:188-193.

McIntosh AS, Savage TN, McCrory P, Fréchède BO, Wolfe R. Tackle characteristics and injury in a cross section of rugby union football. *Med Sci Sports Exerc* 2010b; 42:977-984.

McManus A, Cross DS. Incidence of injury in elite junior rugby union: a prospective descriptive study. *J Sports Sci Med* 2004; 7:438-445.

McMaster DT, Gill N, Cronin J, McGuigan M. A brief review of strength and ballistic assessment methodologies in sport. *Sports Med* 2014; 44:603-623.

Moore IS, Ranson C, Mathema P. Injury risk in international rugby union three-year injury surveillance of the Welsh national team. *Orthop J Sports Med* 2015; 3:2325967115596194.

Morrison I. *Rugby union,* Print book : English : Rev ed, London, Blandford; 1993.

Mullaney MJ, McHugh MP, Johnson CP, Tyler TF. Reliability of shoulder range of motion comparing a goniometer to a digital level. *Physiother Theory Pract* 2010; 26:327-333.

Munro AG, Herrington LC. Between-session reliability of four hop tests and the agility T-test. *J Strength Cond Res* 2011; 25:1470-1477.

Mužek R. Origins and development of rugby. *Polytechnic of Međimurje in Čakovec.* 2015; B.S. Thesis: 32.

NCAA. Sports sponsorship and participation rates report - October 2015. http://www.ncaa.org/about/resources/research/sports-sponsorship-and-participation-research. Accessed 29 July 2016.

Nicholas CW. Anthropometric and physiological characteristics of rugby union football players. *Sports Med* 1997; 23:375-396.

Nicholl J, Coleman P, Williams B. The epidemiology of sports and exercise related injury in the United Kingdom. *Br J Sports Med* 1995; 29:232-238.

Noakes T, Du Plessis M. *Rugby without risk: a practical guide to the prevention and treatment of rugby injuries*, 1st ed, van Schaik; 1996.

Olsen O-E, Myklebust G, Engebretsen L, Holme I, Bahr R. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. *BMJ* 2005; 330:449.

Painkra JP, Kumar S, Anwer S, Kumar R, Nezamuddin M, Equebal A. Reliability of an assessment of deep neck flexor muscle endurance test: a cross-sectional study. *Int J Ther Rehabil* 2014; 21:227-231.

Palmer-Green DS, Stokes KA, Fuller CW, England M, Kemp SP, Trewartha G. Match injuries in English youth academy and schools rugby union: an epidemiological study. *Am J Sports Med* 2013; 41:749-755.

Palmer-Green DS, Stokes KA, Fuller CW, England M, Kemp SP, Trewartha G. Training activities and injuries in English youth academy and schools rugby union. *Am J Sports Med* 2015; 43:475-481.

Paul DJ, Nassis GP, Whiteley R, Marques JB, Kenneally D, Chalabi H. Acute responses of soccer match play on hip strength and flexibility measures: potential measure of injury risk. *J Sports Sci* 2014; 32:1318-1323.

Pearce CJ, Brooks JH, Kemp SP, Calder JD. The epidemiology of foot injuries in professional rugby union players. *Foot Ankle Surg* 2011; 17:113-118.

Peck KY, Johnston DA, Owens BD, Cameron KL. The incidence of injury among male and female intercollegiate rugby players. *Sports Health* 2013; 5:327-333.

Peeler J, Anderson JE. Reliability of the Thomas test for assessing range of motion about the hip. *Phys Ther Sport* 2007; 8:14-21.

Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star excursion balance test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther* 2006; 36:911-919.

Pollock KM. The star excursion balance test as a predictor of lower extremity injury in high school football players. *The University of Toledo* 2010; M.Sc. in Exercise Science.

Pook P. *Complete conditioning for rugby*, Champaign, Ill. : Human Kinetics; 2012.

Prather H, Harris-Hayes M, Hunt DM, Steger-May K, Mathew V, Clohisy JC. Reliability and agreement of hip range of motion and provocative physical examination tests in asymptomatic volunteers. *PM & R* 2010; 2:888-895.

Quarrie KL, Alsop J, Waller AE, Bird Y, Marshall SW, Chalmers D. The New Zealand rugby injury and performance project: VI. A prospective cohort study of risk factors for injury in rugby union football. *Br J Sports Med* 2001; 35:157-166.

Quarrie KL, Cantu RC, Chalmers DJ. Rugby union injuries to the cervical spine and spinal cord. *Sports Med* 2002; 32:633-653.

Quarrie KL, Gianotti SM, Hopkins WG, Hume PA. Effect of nationwide injury prevention programme on serious spinal injuries in New Zealand rugby union: ecological study. *BMJ* 2007; 334:1150.

Quarrie KL, Handcock P, Waller AE, Chalmers D, Toomey M, Wilson B. The New Zealand rugby injury and performance project: III. Anthropometric and physical performance characteristics of players. *Br J Sports Med* 1995; 29:263-270.

Quarrie KL, Hopkins WG. Changes in player characteristics and match activities in Bledisloe cup rugby union from 1972 to 2004. *J Sports Sci* 2007; 25:895-903.

Quarrie KL, Hopkins WG. Tackle injuries in professional rugby union. *Am J Sports Med* 2008; 36:1705-1716.

Quarrie KL, Wilson B. Force production in the rugby union scrum. *J Sports Sci* 2000; 18:237-246.

Rae K, Orchard J. The Orchard sports injury classification system (OSICS) version 10. *Clin J Sport Med* 2007; 17:201-204.

Reid A, Birmingham TB, Stratford PW, Alcock GK, Giffin JR. Hop testing provides a reliable and valid outcome measure during rehabilitation after anterior cruciate ligament reconstruction. *Phys Ther* 2007; 87:337-349.

Rienzi E, Reilly T, Malkin C. Investigation of anthropometric and work-rate profiles of rugby Sevens players. *J Sports Med Phys Fitness* 1999; 39:160-164.

Roberts SP, Trewartha G, England M, Shaddick G, Stokes KA. Epidemiology of time-loss injuries in English community-level rugby union. *BMJ open* 2013; 3:e003998.

Roberts SP, Trewartha G, England M, Stokes KA. Collapsed scrums and collision tackles: what is the injury risk? *Br J Sports Med* 2015; 49:536-540.

Roberts SP, Trewartha G, Higgitt R, El-Abd J, Stokes K. The physical demands of elite English rugby union. *J Sports Sci* 2008; 26:825-833.

Ross A, Gill N, Cronin J. Match analysis and player characteristics in rugby Sevens. *Sports Med* 2014; 44:357-367.

Sankey RA, Brooks JH, Kemp SP, Haddad FS. The epidemiology of ankle injuries in professional rugby union players. *Am J Sports Med* 2008; 36:2415-2424.

Schneiders AG, Takemura M, Wassinger CA. A prospective epidemiological study of injuries to New Zealand premier club rugby union players. *Phys Ther Sport* 2009; 10:85-90.

Schwellnus MP, Thomson A, Derman W, Jordaan E, Readhead C, Collins R, Morris I, Van der Linde E, Williams A. More than 50% of players sustained a time-loss injury (> 1 day of lost training or playing time) during the 2012 super rugby union tournament: a prospective cohort study of 17 340 player-hours. *Br J Sports Med* 2014; 48:1306-1315.

Shaji J, Isha S. Comparative analysis of plyometric training program and dynamic stretching on vertical jump and agility in male collegiate basketball player. *Al Ameen J Med Sci* 2009; 2:36-46.

Smart DJ. Physical profiling of rugby union players: implications for talent development. *Auckland University of Technology, Faculty of Health and Environmental Sciences* 2011; Ph.D. Thesis.

Smith R, Downing W, Thompson D, Fitch S, Bowler S. Reducing the match day injury rate at a semi-professional rugby club: an audit of injury between 2013 and 2015. *Br J Sports Med* 2015; 49:A6-A7.

Smith R, Thompson H, Goodman M. An audit of match day injuries in a semi-professional rugby union team. *Br J Sports Med* 2014; 48:A9-A10.

Strand SL, Hjelm J, Shoepe TC, Fajardo MA. Norms for an isometric muscle endurance test. *J Hum Kinet* 2014; 40:93-102.

Swain MS, Lystad RP, Henschke N, Maher CG, Kamper SJ. Match injuries in amateur rugby union: a prospective cohort study-FICS Biennial symposium second prize research award. *Chiropr Man Ther* 2016; 24:17.

Takemura M, Nagai S, Iwai K, Nakagawa A, Furukawa T, Miyakawa S, Kono I. Injury characteristics in Japanese collegiate rugby union through one season. *Football Science* 2009; 6:39-46.

Tee JC, Klingbiel J, Collins R, Lambert M, Coopoo Y. Preseason Functional Movement Screen component tests predict severe contact injuries in professional rugby union players. *J Strength Cond Res* 2016; 30:3194–3203.

Tong TK, Wu S, Nie J. Sport-specific endurance plank test for evaluation of global core muscle function. *Phys Ther Sport* 2014; 15:58-63.

Trewartha G, Preatoni E, England ME, Stokes KA. Injury and biomechanical perspectives on the rugby scrum: a review of the literature. *Br J Sports Med* 2015; 49:425-433.

Usman J, McIntosh AS. Upper limb injury in rugby union football: results of a cohort study. *Br J Sports Med* 2013; 47:374-379.

Van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. *Sports Med* 1992; 14:82-99.

Vaz L, Morais T, Rocha H, James N. Fitness profiles of elite Portuguese rugby union players. *J Hum Kinet* 2014; 41:235-244.

Veale JP, Pearce AJ, Carlson JS. The yo-yo intermittent recovery test (level 1) to discriminate elite junior Australian football players. *J Sci Med Sport* 2010; 13:329-331.

Viljoen W, Saunders CJ, Hechter GD, Aginsky KD, Millson HB. Training volume and injury incidence in a professional rugby union team. *S Afr J Sports Med* 2009; 21:97-101.

West DJ, Owen NJ, Jones MR, Bracken RM, Cook CJ, Cunningham DJ, Shearer DA, Finn CV, Newton RU, Crewther BT. Relationships between force–time characteristics of the isometric midthigh pull and dynamic performance in professional rugby league players. *J Strength Cond Res* 2011; 25:3070-3075.

Whitehouse T, Orr R, Fitzgerald E, Harries S, McLellan CP. The epidemiology of injuries in Australian professional rugby union 2014 super rugby competition. *Orthop J Sports Med* 2016; 4:2325967116634075.

Wikstrom EA, Tillman MD, Chmielewski TL, Cauraugh JH, Naugle KE, Borsa PA. Self-assessed disability and functional performance in individuals with and without ankle instability: a case control study. *J Orthop Sports Phys Ther* 2009; 39:458-467.

Wilk KE, Meister K, Andrews JR. Current concepts in the rehabilitation of the overhead throwing athlete. *Am J Sports Med* 2002; 30:136-151.

Wilk KE, Reinold MM, Macrina LC, Porterfield R, Devine KM, Suarez K, Andrews JR. Glenohumeral internal rotation measurements differ depending on stabilization techniques. *Sports Health* 2009; 1:131-136.

Williams S, Trewartha G, Kemp S, Michell R, Stokes K. The influence of an artificial playing surface on injury risk and perceptions of muscle soreness in elite rugby union. *Scand J Med Sci Sports* 2016; 26:101-108.

Williams S, Trewartha G, Kemp S, Stokes K. A meta-analysis of injuries in senior men's professional rugby union. *Sports Med* 2013; 43:1043-1055.

Willigenburg NW, Borchers JR, Quincy R, Kaeding CC, Hewett TE. Comparison of injuries in American collegiate football and club rugby: a prospective cohort study. *Am J Sports Med* 2016; 44:753-760.

Wilson E, Fox S, singer A, Cavanagh K. *The sports book: The sports, the rules, the tactics, the tecnics,* 3rd ed, United state, DK publishing; 2013.

World Rugby. 2016-2020 World rugby strategic plan. http://www.worldrugby.org/strategic-plan. Accessed 29 July 2016.

World Rugby. Laws of the Game Rugby Union. http://laws.worldrugby.org/?language=en. Accessed 2015 2 December.

Yard EE, Comstock RD. Injuries sustained by rugby players presenting to United States emergency departments, 1978 through 2004. *J Athl Train* 2006; 41:325-331.