Determining the incidence, risk factors and predictors of injury among male FNB Varsity Cup rugby players in South Africa

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DECLARATION

I, **Renaldo Solomons**, hereby declare that the thesis "**Determining the incidence, risk factors and predictors of injury among male FNB Varsity Cup rugby players in South Africa**" submitted to the University of the Western Cape for the degree of Masters in Biokinetics has not previously been submitted by me for a degree, at this or any other university, that this work is my own in design and execution, and that all the material contained herein have been duly acknowledged by complete references.

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Renaldo Solomons December 2023

DEDICATION

Nobody has been more important to me in the pursuit of this research than my family. I would like to thank my dearest mother, Amanda, and grandparents, Hermanus and Jennifer, for their constant love and guidance in whatever I pursue, and most importantly your prayers. To my sister, Lauren, and niece, Amara, thank you for your constant care. To my partner, I wish to thank you for your invaluable support and for being there every step of the way. The immeasurable support and sacrifices made by all enabled me to further my education, while pursuing my dreams and passion.

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LIST OF ABBREVIATIONS

ACL	– Anterior Cruciate Ligament
CC	– Currie Cup
FMS	– Functional Movement Screening
FNB	– First National Bank
GPS	– Global Positioning System
HIA	– Head Injury Assessment
IOC	– International Olympic Committee
IRB	– International Rugby Board
RICG	– Rugby Injury Consensus Group
RWC	– Rugby World Cup
SARIISPP	– South African Rugby Injury and Illness Surveillance and Prevention Project
SARU	– South African Rugby Union
SPSS	– Statistical Package for the Social Sciences
STROBE-SIS	– Strengthening the Reporting of Observational Studies in Epidemiology – Sports Injury and Illness Surveillance
TMO	– Television Match Officials
TRIPP	– Translating Research into Injury Prevention Practice
VC	– Varsity Cup
WR	– World Rugby
YG	– Young Guns
YRISP	– Youth Rugby Injury Surveillance Project

ABSTRACT

The physical nature of the sport of rugby allows for a high incidence of injury, even in university rugby, compared to other contact sporting codes. Rugby Union lacks injury data focusing on university student-athletes, more specifically in South Africa. Therefore, the aim of this study was to determine the incidence and risk factors of injury, and to predict the risk of injury based on playing position among male rugby players participating in the FNB Varsity Cup Young Guns tournament. The study used a quantitative, cross-sectional and correlational research design. From a population of approximately 360 male rugby players who participated annually in the Young Guns tournament in SA, a study sample of 252 participants were conveniently recruited to participate in this study. An adapted version of the standardised and validated Rugby Union injury questionnaire was used to capture the rugby injury data, such as the location, type, nature, and severity of injury. The injury data collected was captured onto a Microsoft Office Excel 2016 spreadsheet and analysed using SPSS version 28. Descriptive statistical analysis (percentages, means and standard deviations) and inferential statistics (Mann-Whitney U-test, Kruskal-Wallis H-test, Pearson's Chi-square test, and multinomial regression analysis) were used to analyse the data. The statistical significance was set at $p < 0.05$. The total number of injuries sustained was 107 for the entire tournament, which translates into an incidence of injury of 9.5 injuries per 1000 hours of player exposure or 136.5 injuries per 1000 playing-hours and 0.6 injuries per 1000 training-hours. The incidence of match injury for the backs (150.6 injuries/1000 match-hours) was greater than that for the forwards (124.1 injuries/1000 match-hours). The shoulder (24 injuries, 23.8%, 95% CI: 14.9% to 30.5%) accounted for the anatomical location that sustained the most injuries, while ligament injury (36 injuries, 35.6%, 95% CI: 25.3% to 45.9%) was the most common type of injury sustained. Most of the injuries sustained were moderate (30 injuries, 29.7%, 95% CI: 22.8% to 36.0%) in severity. Contact events (91.1%, 95% CI: 86.1% to 96.4%) caused the most injuries due to tackling (28.7%) and collision (13.9%) during match-play. The number 8 (11.9%), inside centre (11.9%) and fullback (9.9%) were the positions that sustained the highest rate of injury amongst the starting fifteen players. The majority of injuries sustained by the Young Guns players was in the second half of match-play (47.5%, 95% CI: 39.6% to 58.4%), while the third-quarter of match-play was responsible for the highest incidence of injury (26.7%, 95% CI: 17.8% to 36.6%). Regression analysis showed that playing between the opposition-22 and

the halfway line of the field (p = 0.035), during either the first or second quarter of match-play (p = 0.047 and p = 0.014, respectively), were significant predictors of injury for both forwards and backs.

This study confirms the high incidence of injury in the Varsity Young Guns rugby tournament. Furthermore, the rate of injury was greater in matches than in training. It is recommended that prospective, incidence-based studies are used to determine precisely the incidence, nature, severity and mechanism of injury. It is suggested that a consistent injury surveillance programme be implemented, specifically within Varsity Cup rugby, which may reflect the need for more broad-based injury surveillance programmes in Varsity Sports in general, in order to assist, support and improve the current injury prevention strategies and implement new ones.

Keywords: Varsity Cup, Young Guns, bio-bubble, injury incidence, injury severity, Rugby Union.

CHAPTER ONE: INTRODUCTION TO THE STUDY

1.1 Introduction

This initial chapter introduces the research study that focuses on the incidence of injury within Rugby Union in South African university rugby players. The chapter provides a background of the study, a statement of the problem, and the aim and objectives of the study. Furthermore, the significance of the study is emphasized to elaborate on the potential value of this research. In addition, the theoretical framework and definitions of terms are included.

1.2 Background of the Study

The game of rugby is a contact sport, which requires constant physical engagement of players, as opposing teams contest for possession of the ball (Burger, Lambert, Viljoen, Brown, Readhead *et al.*, 2017). In South Africa, numerous top universities across the country participate in four different leagues, in what is known as Varsity Rugby (van Heerden, 2016). The FNB Varsity Cup rugby competition is one that has a rich culture within university sport for full-time students in South Africa (Donkin, Venter, Coetzee, & Kraak, 2020). Initiated in 2008, eight of the premier division teams participated in the Varsity Cup tournament, while their respective internal champions competed in the residence or koshuis league tournament (van Heerden, 2016). The second division tournament, called the Varsity Shield, was launched in 2011, and this competition was followed by the Young Guns tournament for the Under-20 rugby players that was associated with each Varsity Cup team and was first implemented in 2012 (van Heerden, 2016). Annually, the Varsity Cup (VC) rugby competition implements new rules and law changes ensuring the Young Guns tournament stays the most innovative and stimulating in South Africa (Donkin *et al.*, 2020).

The physical nature of the game allows for a high incidence of injury compared to other contact sporting codes (Fuller, Taylor, Douglas, & Raftery, 2020). Rugby Union has an above-average incidence of injury, which is higher than the overall incidence in cricket, soccer or ice hockey (Brown, Verhagen, Viljoen, Readhead, Van Mechelen *et al.*, 2012). However, participating in any team sport that involves moderate-to-vigorous physical activity, such as rugby, is also accompanied by numerous physical, mental, and social benefits (Griffin, Perera, Murray, Hartley, Fawkner *et al.*, 2021).

Appropriate training in rugby needs to be accompanied by sport-specific adaptations that enable players to perform accordingly (Burger *et al.*, 2017). Amateur players are often exposed to limited physical conditioning sessions and insufficient technical training sessions, outside of matches (Barrett, 2015). Often, the lack of physical conditioning and technical training sessions places players at risk of injury, as their insufficiently conditioned bodies now become incapable of coping with the physical demands of the game (Barrett, 2015). Due to the game constantly evolving, there are greater demands and expectations placed on the players' health- and skill-related fitness components that are required to play the game competitively (Hillhouse, 2013).

Furthermore, amateur players may be at an increased risk of injury, due to improper biomechanical techniques during game-play, the inability to access appropriate healthcare, and the lack of knowledge or experience of coaches to implement appropriate safety protocols during training and matches (Kaplan, Goodwillie, Strauss, & Rosen, 2008). Acquiring knowledge of injury data allows for the mitigation of risk through appropriate player education and the application of technical training sessions (Barrett, 2015). This will also assist the International Rugby Board (IRB), when adjusting the laws of the game from sub-elite to elite levels to minimize the number of injuries that occur (Hillhouse, 2013).

The incidence of injury in rugby continues to remain high, and several studies were undertaken to address the nature, incidence, and mechanisms of injury associated with rugby (Fuller, Raftery, Readhead, Targett, & Molloy, 2009; Roberts, Trewartha, England, Shaddick, & Stokes, 2013; Yeomans, Kenny, Cahalan, Warrington, Harrison *et al.*, 2018). The incidence, severity, and nature of injury remains largely unknown at an amateur level, as it is difficult to generalize data from the professional game to the amateur level, due to variations in the physical demands, style, and intensity of play between the two levels (Bleakley, Tully, & O'Connor, 2011). Changes within the game, such as sport-specific tactics and alterations linked to the laws, could possibly account for the increased prevalence of injury in the sport recorded over time, due to the risk associated with the positional arrangement of players (Hillhouse, 2013).

Injury prevention strategies are continuously developed to prevent injuries and to rehabilitate players from injury (Louw, Morris, & Crous, 2019). When determining the incidence of injury for the amateur cohort, in-depth and precise injury data is needed that can positively impact injury prevention strategies (Bleakley *et al.*, 2011). An effective method of extracting information regarding the incidence, type, and severity of rugby injury could be made possible by conducting a survey and making use of a questionnaire (Louw *et al.*, 2019). Questionnaires, when properly compiled and administered, can provide a wide range of research data regarding player profile and injury that could indicate areas of concern (Louw *et al.*, 2019). In 2007, the IRB developed definitions and procedures to improve the quality of research data collected and reported in future studies on Rugby Union (RU) injuries, as there had previously been difficulty collecting and comparing data without a standardised acceptable method of research (Kaux, Julia, Delvaux, Croisier, Forthomme *et al.*, 2015). While robust injury surveillance systems and interventions have been introduced in professional sport, similar strategies are also required in amateur sport (Yeomans *et al.*, 2018).

The South African Rugby Injury and Illness Surveillance and Prevention Project (SARIISPP), which was introduced by the South African Rugby Union (SARU), has been compiling standardized injury data of tournaments since 2011, but only at the youth level (Paul, Readhead, Viljoen, & Lambert, 2020). The data extracted provides insight into (1) the injury profiles of players participating in these tournaments, (2) how the game has evolved over time, and (3) areas that may need highlighting and appropriate interventions implemented in order to ensure player safety (Starling, Readhead, Viljoen, Brown, Sewry *et al.*, 2018).

The physical nature of team sports is challenging on players who return to the field of play post-injury (Chen & Kelly, 2020; Rafferty, Ranson, Oatley, Mostafa, Mathema *et al*., 2019; Robyn, 2022). World Rugby, therefore, developed return-to-play guidelines, allowing unions to prepare their players to effectively return to training and match-play (Chen & Kelly, 2020). In 2020, the Varsity Cup (VC) board suspended the entire rugby season, due to the rapid rise and spread of COVID-19 (Varsity Cup Suspends 2020 Season Following Coronavirus Outbreak, n.d.). In 2021, the competition then returned to normal, which required university rugby players and staff to enter a bio-bubble in order to make competition safe (*FNB Varsity Cup Village — What You Need to Know*, n.d.). This reduced the chance of staff and players contracting the virus and, thereby, reducing the number of hospital admissions and intensive care cases (Dores & Cardim, 2020).

There is a need to constantly investigate the full extent of the injury conundrum, and potential risk factors associated with injury, within university rugby to mitigate identified risks and promote the benefits associated with participation (Swain, Lystad, Henschke, Maher, & Kamper, 2016). The aim of the present study was to determine the incidence, location, type, and severity of injury sustained by Varsity Cup Young Guns players over one competitive season. This study is important as it adds to the limited number of epidemiological studies that focus on injuries in Rugby Union players, while the research findings will provide the motivation for evidence-based guidance and recommendations to medical practitioners and coaches to reduce the injury rate (Cross, 2016; Holtzhausen, Schwellnus, Jakoet, & Pretorius, 2006; Morkel, 2016; Murias-lozano, Mendía, Sebastián-Obregón, Solís-Mencia, Hervás-Pérez *et al*., 2022).

1.3 Statement of the Problem

Rugby is associated with a high risk of injury, with amateur players more prone to injury in comparison to professional players (Oudshoorn, Driscoll, Kilner, Dunn, & James, 2017). The injury profile at the professional level is well-established in the literature (Barrett, 2015) but, according to Finch (2012), may not be as well-established at the amateur level.

Gabbett and Jenkins (2011) reported that the harder rugby players trained, the more injuries they sustained, suggesting that field injuries were indirectly influenced by the high strength and power training loads associated with the sport. Millson (2018) explained that the rugby training strategy and volume may affect the injury rate of players over a season, i.e., for each week of additional preseason training that a player attended, there was a 3.9% increase in relative risk of injury.

Time-loss injuries were more prevalent at higher levels of community rugby (Roberts *et al*., 2013). If coaches had a better understanding of the mechanisms of injury, and implemented safe and effective tackling techniques, then players would be less at risk of sustaining tackle-related injuries (Sobue, Kawasaki, Hasegawa, Shiota, Ota *et al*., 2018).

Williams *et al*. (2016) explained that the prevention of injuries was crucial to a team's success in the long run. They also suggested that a multidisciplinary approach, including medical, rehabilitative and conditioning staff, were all required to help prevent the occurrence of injuries and improve the players' availability to play competitively, which ultimately increased the team's chances of success. Therefore, research on injury prevalence and incidence needs to be conducted in order to gain more knowledge about these potentially debilitating aspects of the sport (Williams, Trewartha, Kemp, Brooks, Fuller *et al.*, 2016).

Currently, there is little or no accurate injury surveillance literature investigating the epidemiology of injuries within university rugby, since the inaugural competition, despite the extensive anecdotal evidence of the high injury incidence at this level of play (Brown *et al*., 2012; Hillhouse, 2013). More specifically, there is a scarcity of studies focussing on the Under-20 or junior rugby players competing at different levels of rugby (Lombard, Durandt, Masimla, Green, & Lambert, 2015). Therefore, to ensure player safety, injury prevention strategies should be implemented to reduce player susceptibility to injury (Hillhouse, 2013).

Rugby players are exposed to different and unique demands, due to their position on the field (Pasqualini, Rossi, De Cicco, Tanoira, Hidalgo *et al*., 2021). Investigating the injury profiles of individual playing positions has not been initiated to any great extent yet, especially in SA (Brooks & Kemp, 2011). Therefore, an improved understanding of the influence of a player's position on injury risk can assist the coaching staff and medical professionals to implement more effective intervention and rehabilitative strategies (Pasqualini *et al*., 2021).

Due to the lack of resources and minimal contact between amateur players and medical professionals, injury surveillance of amateur cohorts is more taxing to complete than in a professional setting (Yeomans *et al*., 2018). The increase in injury incidence within all levels of rugby in South Africa, more specifically within universities and clubs, is an enormous challenge that needs to be addressed (Van Niekerk & Lynch, 2012). Many regulations that have been unexpectedly implemented and modified during the COVID-19 pandemic could impact the players' risk of injury when returning to play, due to the potentially heightened levels of anxiety of players (Chen & Kelly, 2020). Players participating in team sports are at potential risk of person-to-person transmission of the Corona virus, due to the increased rate of respiration during training and matches, whilst performing activities in close proximity to other players (Jones, Phillips, Beggs, Calder, Cross *et al*., 2021).

A number of prospective studies investigated the injury epidemiology within elite or junior player cohorts (Swain *et al.*, 2016; Viviers, Viljoen, & Derman, 2018). To the best of the author's knowledge, no injury surveillance studies investigating the number and type of injuries sustained during the FNB Varsity Cup Young Guns tournament have been conducted. Therefore, the lack of epidemiological research regarding the incidence and characteristics of injuries in the Young Guns competition provided the motivation to conduct the present study (Falkenmire, Manvell, Callister, & Snodgrass, 2020; Hillhouse, 2013; Murias-lozano *et al*., 2022).

1.4 Aim of the Study

The aim of the study is to determine the incidence and risk factors of injury, and to predict the risk of injury based on playing position among male rugby players participating in the FNB Varsity Cup Young Guns tournament.

1.5 Objectives of the Study

The objectives of the study are to:

- Determine the incidence of injuries amongst male Varsity Cup rugby players.

- Determine the location, type and severity of injury.
- Determine the phase of play that contributed the most to injury occurrence.
- Determine the playing positions that contributed the most to injury.
- Determine the risk factors associated with playing position.
- Determine the association between anthropometric characteristics, playing position and risk of injury.
- Predict the risk of injury based on rugby playing position.

1.6 Hypothesis of the Study

The following hypotheses were applied in the study, namely:

- The male Varsity Cup rugby players will have a high incidence of injuries.
- The most common sites of injury will include the lower body and the shoulder.
- The tackling phase of play will contribute the most to player injury.
- Forwards will sustain more upper body injuries, while backline players will sustain more lower body injuries, and the flankers will be the most injury-prone position.
- There will be statistically significant associations between the players' anthropometric characteristics, playing position and risk of injury.
- The risk factors significantly associated with rugby injury will include previous injury, playing position and foul play.
- Certain players will be at higher risk of injury based on playing position.

1.7 Significance of the Study

The introduction to professionalism in Rugby Union was accompanied by an increase in injuries to players, at both the amateur and professional levels (Oudshoorn *et al.*, 2017). Despite extensive reporting on the prevalence of injuries at the national and international levels, there remains a lack of injury data on amateur Rugby Union competitions (Tondelli, 2020), and particularly when focusing on FNB Varsity Cup players in SA.

Rugby is associated with a significant proportion of injuries, with the tackle phase of play a leading contributor to injuries (Mathewson & Grobbelaar, 2015). Louw *et al.* (2019) suggested that with high injury incidence rates, greater efforts should be focused on collecting epidemiological data, which will ultimately broaden the base of knowledge on injuries, and provide suggestions to coaches and players on how to reduce the risk of injury within contact sport.

It is important to record the incidence, nature and mechanisms of injury, as a vital first step towards an injury prevention plan (Morkel, 2016). It is also noted that injury surveillance was mainly reported at the professional level, but comprehensive player monitoring is still lacking at the amateur level (Oudshoorn *et al.*, 2017). The collection and reporting of injuries for surveillance and research purposes has seen an impressive improvement across a broad spectrum of applications, ranging from individual to team sports and from youth to master's level sports (Bahr, Clarsen, Derman, Dvorak, Emery *et al.*, 2020).

All injuries should be documented by the team's medical staff, as they may have an impact on a player's future performance and/or contribute to recurring and/or other preventable injuries (Hillhouse, 2013). Rugby exposure data should also be collected to ascertain the true prevalence of injuries in Rugby Union competitions, as there is a limited number of injury surveillance studies at amateur-level that report on the common injuries prevalent in forwards and backline players (Hillhouse, 2013). This data can then aid in developing preventative techniques to minimize the occurrence of injuries.

Injury prevention strategies can best be formulated and implemented, if one has a good understanding of the true prevalence and nature of injuries within contact sport (Yeomans e*t al.*, 2018). Consequently, once injury prevention strategies are implemented, injury surveillance should constantly be repeated to assess the effectiveness of these strategies (Barrett, 2015).

By gathering important information about injuries, this data can be used to educate players and coaches, which could ultimately reduce the prevalence of injuries (Sobue *et al.*, 2018). Starling *et al.* (2018) concluded that teams which had lower burdens of injury, also performed better in tournaments overall. Future studies should be initiated to compare injury incidence and prevalence data, both locally and internationally (Louw *et al.*, 2019). Designing and evaluating injury prevention strategies require continuous and accurate collection of injury data but, unfortunately, the timely process of systematic data collection is rare (Ekegren, Gabbe, & Finch, 2016).

Combining position-specific differences on injury profiles and player injury history could lead to a more effective and unique injury prevention strategy within the sport (Brooks & Kemp, 2011). A thorough understanding of the game, including the demands of playing positions, is required to develop and implement unique conditioning programmes for players (Donkin *et al*., 2020). This supports the idea of a holistic understanding of the incidence, nature and severity of injury to effectively minimize injuries within rugby, as indicated by the TRIPP Model (Yeomans *et al*., 2018). It is of utmost importance to correctly record and categorise injuries according to standardised definitions in order to avoid any inaccuracies, such as the underreporting or overestimation of injury incidence (Finch & Cook, 2013). The opinion of healthcare professionals at amateur and club is important, as their knowledge significantly impacts short-term risk of injury or re-injury, the consequences of infection on injury risk, and other debilitating criteria on the injury risk of players (Chen & Kelly, 2020).

Sociodemographic information and performance data based on Under-20 rugby players are important, since up to 32.0% of players participating at the Under-20 international level are recruited into the senior national teams (Parker, 2013). This, therefore, emphasises the importance of possessing research data as reference information for junior professional rugby players in order to adequately prepare and adapt them for rugby at the senior level (Lombard *et al.*, 2015).

1.8 Theoretical Framework

The current study is based on two theoretical models, namely, the Health Belief model and Translating Research into Injury Prevention Practice (TRIPP) model.

1.8.1 Health Belief Model

The Health Belief model (HBM) consists of six divisions, and predicts preventative health behaviour through participating in sport, by stating that people's beliefs influence their health-related behaviours (Hartley, 2018). The six divisions are: (a) perceived susceptibility, (b) perceived severity, (c) perceived benefits, (d) perceived barriers, (e) cues to action, and (f) self-efficacy (Hartley, 2018). According to this model, participation is based on beliefs, e.g., physical inactivity, which is a threat to an individual's health, and the benefits of participating in physical activity and sport outweigh the setbacks (Luquis & Kensinger, 2019; Sas-Nowosielski, Hadzik, Gorna, & Grabara, 2016).

Participation in sport has many health benefits, however, excessive practice and exposure to competitive conditions are associated with an increased risk of injury (Lemoyne, Poulin, Richer, & Bussières, 2017). Sustaining any injury results in an absence from training and matches, and could possibly lead to a player becoming overweight or suffering from post-traumatic osteoarthritis (Richmond, Fukuchi, Ezzat, Schneider, & Schneider, 2013). Therefore, research emphasizes the importance of improving the players' understanding of injury, thus, investigating the risk of injury will be beneficial in promoting good health (Richmond *et al.*, 2013). Understanding a player's attitude and behaviour about safety should also be investigated, as they have been identified as risk factors for injury (Hendricks, Den Hollander, Tam, Brown, & Lambert, 2015).

Understanding the incidence of injuries across an entire playing season helps to ensure that specific time and attention are targeted at addressing common injuries and applying preventative measures accordingly (Bittencourt, Meeuwisse, Mendonca, Nettel-Aguirre, Ocarino *et al.*, 2016). Figure 1.1 suggests that a plan of action can be adopted in order to understand the prevalence of injury, and identify players who are at increased risk, as well as common injury patterns, with the initial step of intervention involving creating an awareness of when, where, and how players sustain specific injuries (Roe, Malone, Blake, Collins, Gissane *et al.*, 2017). Until risk management techniques are incorporated into team programmes, it is important to understand the effects of injury on the players' availability, perceived success, and potential likelihood of experiencing re-injury (Bittencourt *et al.*, 2016).

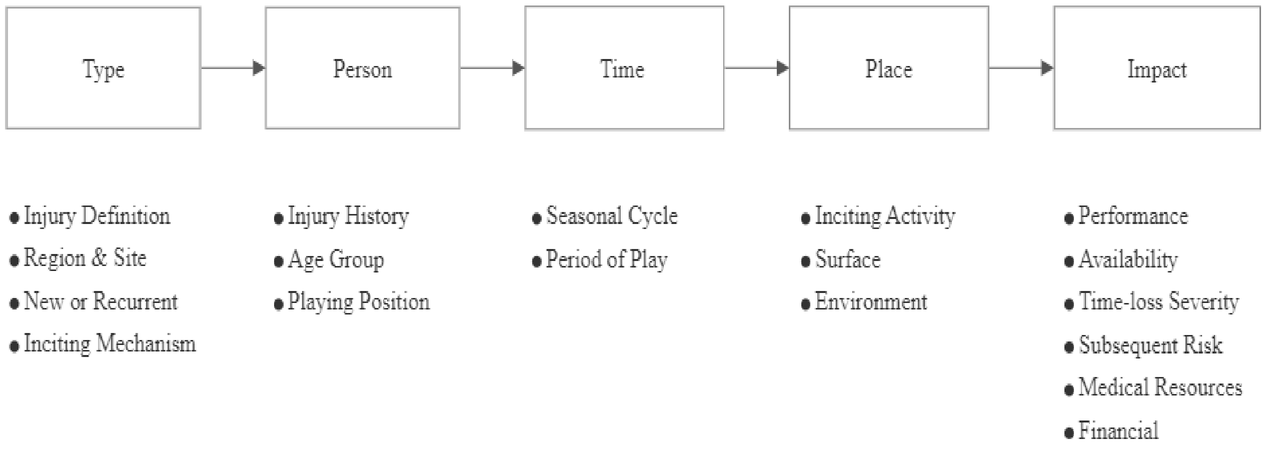

Figure 1.1: Understanding when, where, and how certain players sustain injury in sport (Roe *et al*., 2017).

Figure 1.1 suggests that there will be repeated changes in vulnerability to injury, while participating in sport, and that exposure to risk factors can create adaptations and change the level of risk over time (Bittencourt *et al*., 2016). It also indicates that the possibility of sustaining an injury is related to many interconnected factors stemming from either positive (i.e., increased fitness) or negative adaptations (i.e., previous injury) (Bittencourt *et al.*, 2016).

1.8.2 Translating Research into Injury Prevention Practice (TRIPP) Model

The TRIPP model, consisting of six stages, was developed for the sporting community in order to have a standard health intervention model that addresses injury and injury prevention (Finch, 2006). This model shows that effective and appropriate measures will be introduced, if they become an integral part of a team's functioning and are adopted successfully (Hillhouse, 2013).

The TRIPP model consists of 6 stages, as indicated in Figure 1.2 below:

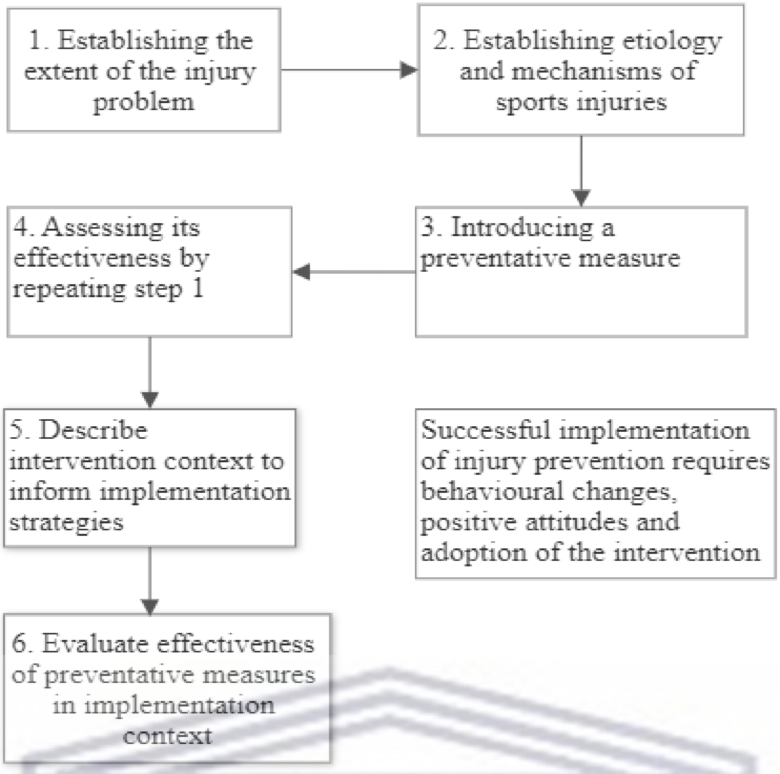

Figure 1.2: Translating Research into Injury Prevention Practice (TRIPP) model (Finch, 2006).

The TRIPP model is derived from, and is an expanded version of the Sequence of Prevention model, as indicated in Figure 1.3 (Barrett, 2015; Bitchell, Varley-Campbell, Robinson, Stiles, Mathema *et al.*, 2020; Garnett, 2018; Hillhouse, 2013; Roe *et al.*, 2017). This model was developed by van Mechelen and aimed to identify prevention measures to reduce sport-specific injuries (Van Mechelen, 1997). According to this model, firstly, injuries are presented according to their incidence and severity. Secondly, there is an attempt to determine the contributing factors or underlying causes of injury. Thereafter, the specific measures should be developed and implemented based on the second step, which aim to reduce the risk and/or severity of injury. Finally, the effect and success of the implemented strategy is then evaluated by means of another, more thorough, injury surveillance exercise (Van Mechelen, 1997).

The players, coaching staff and various sporting codes could accept, implement and adhere to the prevention model in order to benefit from the positive outcomes it produces (Barrett, 2015). Recent studies suggest that injuries sustained by participating in sports are preventable, as many sports, including soccer and rugby, have demonstrated a decrease in the injury incidence, especially during implementation of the post-injury prevention strategy (Ekegren *et al*., 2016).

The third step, introducing and implementing a potential preventative strategy, is based on the results that are acquired from the first two steps (Finch, 2006). The efficacy thereof is then assessed and evaluated in the fourth step, by repeating the first step, i.e., establishing the extent of the (injury) problem, by utilizing a random yet controlled sample (Bjørneboe, Flørenes, Bahr, & Andersen, 2011). The remaining two steps emphasise the importance of implementing preventative strategies and the need to ensure their broad acceptance (Finch, 2006).

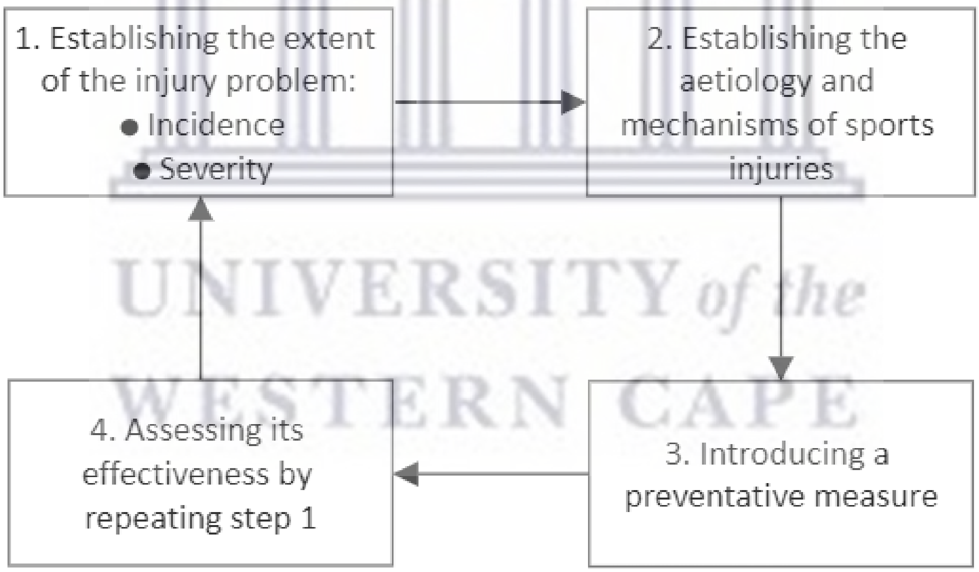

Figure 1.3: The Sequence of Prevention model (Van Mechelen, 1997).

In summary, the six-staged TRIPP framework guides medical professionals with regard to managing injuries through: identifying possible injury trends and risk factors (stages 1 and 2), profiling the capabilities of players in comparison to the demands of the sport (stages 3 and 4), and assessing the players' responses to the interventions through player monitoring (stages 5 and 6) (Roe *et al.*, 2017).

1.9 Definition of Terms

BokSmart is a national rugby safety programme that was established by SARU and the Chris Burger/Petro Jackson Players Fund that aims to prevent injury and enhance player performance by means of implementing evidence-based sports medicine and training strategies in South Africa (Viljoen & Patricios, 2012).

Injury is any physical complaint reported by a player during a rugby match or during rugby training (Fuller, Molloy, Bagate, Bahr, Brooks *et al.*, 2007).

Injury incidence is the number of new cases of an injury in a population, in a prospective given time span (Bjørneboe *et al.*, 2011).

Injury severity is determined by considering the amount of days absent from the time of injury onset up to the date of return to full participation in a sport. Injuries are grouped according to the number of days taken for full recovery, i.e., 0–1 days (slight), 2–3 days (minimal), 4–7 days (mild), 8–28 days (moderate), more than 28 days (severe) (Bahr *et al.*, 2020; Fuller *et al.*, 2007).

Medical attention injury is an injury caused by an event that prevents a player from playing in matches or participating in training, and requires special medical treatment (medication, suturing, radiographs, etc.) (Fuller *et al.*, 2007).

Player durability or resilience refers to a player's ability to tolerate the physical and mental demands of their sport, without sustaining significant injury (Williams *et al.*, 2016).

Rugby Union is a sport played by two opposing teams consisting of 15 players each contesting for a ball in order to score points within the laws of the game (Fuller *et al.*, 2007).

Varsity Cup is the premier division inter-university rugby competition in South Africa that aims to promote young rugby talent at university level (Hillhouse, 2013; Potgieter, Visser, Croukamp, Markides, Nascimento *et al.*, 2014, Schoeman & Schall, 2020).

Young Guns is a tournament for the Under-20 or junior side of each Varsity Cup team (van Heerden, 2016).

CHAPTER TWO: REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter focuses on reviewing the literature associated with the incidence of injury in Rugby Union. Injury epidemiology research focuses on the occurrence of injury, location and type of injury, identifying possible risk factors, the effects of the various risk factors, and evaluating previously developed and implemented injury prevention strategies (Bahr *et al*., 2020; Barrett, 2015; Brooks, Fuller, Kemp, & Reddin, 2005; Cross, 2016; Ogaki, Otake, Nakane, Kosasa, Kanno *et al.*, 2020). In addition, the following review includes injury specific playing positions and the phase of play in which injury was sustained.

Rugby players are exposed to heavy training loads and matches, and encounter frequent collisions, resulting in the higher risk of injury (Viljoen, Schoeman, Brandt, Patricios, & van Rooyen, 2017). These events are accompanied by repetitive microtrauma from tackles and frequent player contact, which often lead to acute and chronic traumatic injuries (Brooks & Kemp, 2011; Tondelli, 2020). According to Swain *et al*. (2016), the rate of injury differs across the different levels of play, with professional players having a higher rate of injury followed by amateur players. Despite the vast body of research on professional rugby players at national and international levels, there is little-to-no conclusive data on the prevalence of injuries among amateur rugby academy players, and university players in particular (Tondelli, 2020).

2.2 Injury Incidence During Training and Matches

The implementation of research to determine the incidence, nature and associated risk of injury has gained increased attention in recent years (Cruz-Ferreira, Cruz-Ferreira, Ribeiro, Santiago,

& Taborda-Barata, 2018). A higher incidence of injury has been reported among youth rugby players in comparison to senior players, especially during matches, due to them not meeting the physical demands of the game or incorrect tackle techniques (Cruz-Ferreira *et al*., 2018; Hillhouse, 2013; Morkel, 2016; Ogaki *et al*., 2020; Solis-Mencia, Ramos-Alvarez, Murias-Lozano, Aramberri, & Salo, 2019).

A study on senior Portuguese rugby players found an incidence rate of 66.6 injuries/1000 match-hours, which is fairly similar to that sustained by Namibian amateur club players (74.4 injuries/1000 match-hours) (Cruz-Ferreira *et al*., 2018; Morkel, 2016). The male amateur rugby union players from the University of Newcastle Rugby Club sustained a total of 207 injuries across one season of 18 matches. This equated to an injury incidence of 164.0 injuries/1000 match-hours, which was considered to be high (Falkenmire *et al*., 2020). The study completed by Solis-Mencia *et al.* (2019) on elite Under-18 Spanish rugby players is a good illustration of the incidence of injury being higher during matches (138.0 injuries/1000 match-hours) than during training (1.2 injuries/1000 training-hours) (Solis-Mencia *et al.*, 2019). These results are supported by a significant body of literature as well (Morkel, 2016; Ogaki *et al*., 2020; Starling, Readhead, Viljoen, Paul, & Lambert, 2021; Starling *et al*., 2018).

Table 2.1 depicts a list of studies on the match, training and overall incidence of injury across various competitions in South Africa. The studies found that match injury incidence was greater than that of training, and that the match injury incidence increased over the years.

Table 2.1: The match, training and overall incidence of injury for studies conducted in South African Rugby Union.

References	**Level of Play**	**Match Incidence** (injuries/1000 player-hours)	**Training Incidence** (injuries/1000 player-hours)	**Overall Incidence** (injuries/1000 player-hours)
Holtzhausen *et al*. (2006)	Super Rugby	55.4	4.3	11
Hillhouse (2013)	Varsity Cup	89	1.58	6.1
Starling *et al*. (2021)	Currie Cup	91	2.6	-
Buchholtz *et al*. (2022)	Super Rugby	241	3.3	12.7

2.3 Risk Factors Associated with Injury

Sport-related injuries are the result of a complex interaction of various risk factors, of which, only a few have been identified (Bahr & Holme, 2003). To improve one's understanding and knowledge of the risk factors associated with rugby injury, the mechanisms by which they occur must also be identified in order to develop and implement effective injury preventive strategies (Bahr & Holme, 2003; Hägglund, 2007). A multidimensional approach is required to examine the aetiology of sports injuries and the various risk factors thereof, due to the fact that these determinants are multifactorial in nature (Hägglund, 2007). An examination of these determinants or potential risk factors considers all factors and sequences of events, prior to the athlete sustaining an injury (Bahr & Holme, 2003). Figure 2.1 is an example of a dynamic model that Meeuwisse used to describe the role played by various factors in the occurrence of injury (Bahr & Holme, 2003; Meeuwisse, 1994). This model suggests that an athlete has an extensive amount of predisposing intrinsic risk factors for injury (e.g., age, gender, body composition, etc.) and once predisposed, an extrinsic risk factor (e.g., environment, equipment, etc.) increases the risk of injury occurring. If both these conditions are present in a susceptible player, then all it takes is an inciting event (e.g., playing situation) for an actual injury to occur

(Hägglund, 2007). Therefore, the risk of injury is a consequence of the balance between a competitive player's intrinsic risk factor profile and exposure to the extrinsic risk factors (Cross, 2016).

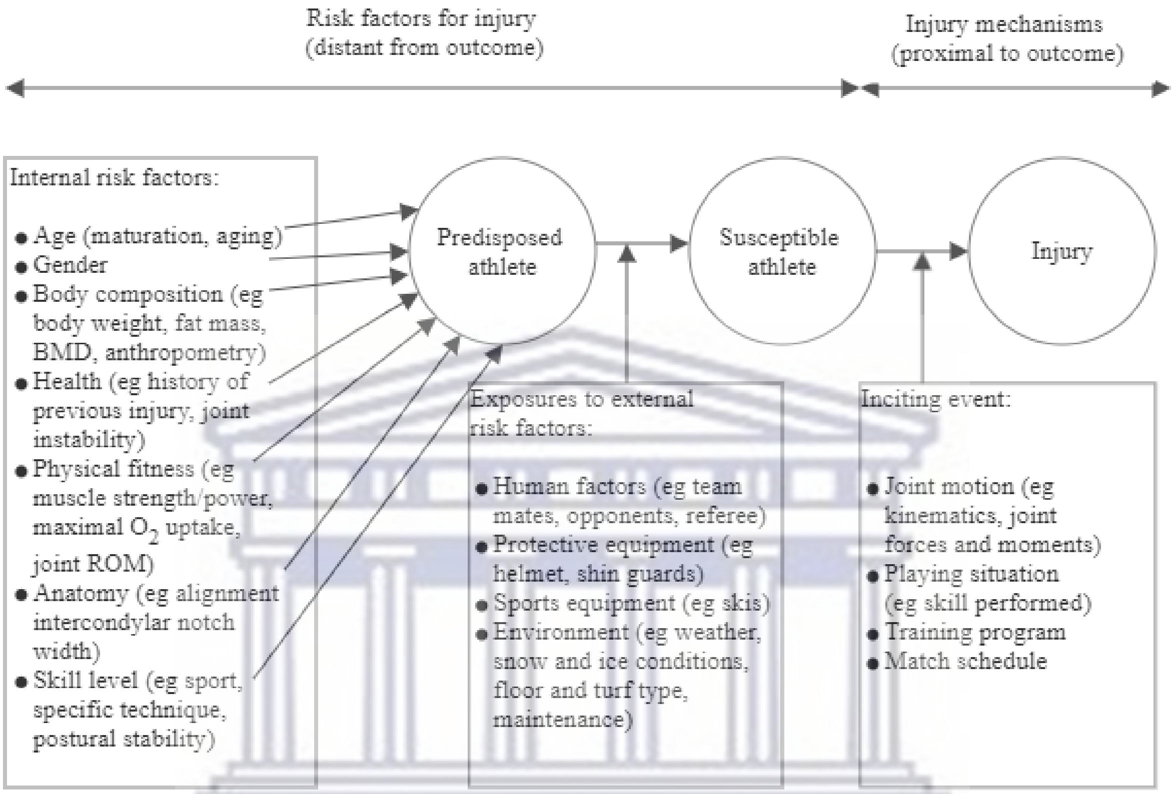

Figure 2.1: A dynamic, multifactorial model of sports injury aetiology (Bahr & Holme, 2003).

Rugby consists of various risks that predispose amateur players to injury (Viljoen *et al.*, 2017). These risk factors assist in identifying how injuries are caused (Bahr & Holme, 2003). Players who are, seemingly, aerobically fitter tend to have a more effective tackling technique (Gabbett, 2008; Den Hollander, 2020). A significant relationship was found between maximal oxygen uptake, agility, and fatigue-induced decrements in tackling technique (Gabbett, 2016).

A player's tackling technique was progressively reduced due to fatigue, resulting in a higher injury risk (Gabbett, 2016).

Almăjan-Guţă *et al*. (2015) investigated the possible relationship between injury frequency and body composition of elite Romanian rugby players. The study reported that injuries sustained by rugby players correlated significantly with their body weight. In another study, half-backs, who had a lower body mass than players in other playing positions, experienced a higher concussion rate (Chéradame, Piscione, Carling, Guinoiseau, Dufour *et al*., 2021). However, Ezzat *et al*. (2016) found that overweight youth had an increased risk of injury (Ezzat, Schneeberg, Koehoorn, & Emery, 2016). The risk of injury was also higher in players who smoked cigarettes, and who had strength and flexibility deficits (Ezzat *et al*., 2016). These results indicated that injury-risk could be identified by means of fitness testing, highlighting the importance of constantly monitoring body composition, such as body fat, lean muscle mass and body water content (Almăjan-Guţă, Rusu, Nagel, & Avram, 2015).

The recent trends in incidence and severity of injury within Rugby Union could be attributed to the higher level and intensity of competition, which requires more frequent ball contention, leading to an increased risk of injury (Viviers *et al*., 2018). In addition, other factors which could influence the incidence of injury include time of the game or season, phase of play, recovery strategies that were utilized, environmental factors and the use of protective equipment (Hillhouse, 2013). Professionalism within teams is accompanied by a higher risk of injury, as injuries within professional teams occur every 59 minutes, with these players sustaining a higher number of recurrent injuries, which was more evident in the earlier stages of the season (Garraway, Lee, Hutton, Russell, & Macleod, 2000).

A player's physical condition and technical ability are areas that develop and improve with maturity and the level of competition that potentially decrease the risk of catastrophic injury

(Viviers *et al*., 2018). Constantly changing environments, such as unstructured contact training sessions, also expose players to a greater risk of injury (Den Hollander, 2020). Emphasis should be placed on establishing training loads that maintain or increase the performance of players, whilst reducing position-specific injury risk (Hillhouse, 2013).

Foul play is rarely penalized by referees and is a relatively common cause of injury, as 5.0% of injuries originate from foul play (Kaux *et al*., 2015). This is one of the most important extrinsic injury risk factors, as there is a significant association between foul play and the number of injuries (Ryynänen, Dvorak, Peterson, Kautiainen, Karlsson *et al*., 2013).

With regard to tackling, a referee usually has the final ruling as to whether a tackle is legal or illegal (Martin, Patel, & Hendricks, 2021). Not all high-risk tackles are illegal, but they might still influence a referee's decision, as they may be considered dangerous and expose a player to the potential risk of injury (Martin *et al*., 2021).

The time during the game could also be a risk factor for injury. Kaux *et al*. (2015) found that between 30.0% and 45.0% of injuries were sustained during the first-half, and between 55.0% and 70.0% during the second. Therefore, injuries were more likely to occur during the second-half than the first. It is a general trend that many injuries occur as the match progresses, but the most crucial playing quarters being the second and fourth quarters, with 35.0% of injuries occurring in the last 20 minutes of the match (Kaux *et al*., 2015).

Due to the contact nature of the game, players are constantly exposed to impact and collision situations that occur mainly through the tackle phase of play, during training and competitive matches (Sinclair, 2009). Protective equipment was introduced to protect players from sustaining injury, and has the potential to improve the safety of the game (Barnes, Rumbold, & Olusoga, 2017; Chalmers, Samaranayaka, Gulliver, & McNoe, 2011; Sinclair, 2009). To gain maximal benefit from utilizing personal protective equipment, the apparel should protect the intended area, provide comfort, and not restrict the player or interfere with the activity and match performance (Anderson & Hall, 1995; Hodgson, 1991). Multiple studies found that using a mouth-guard was more beneficial, especially when controlling fragmented teeth and head acceleration (Sinclair, 2009). Players were 1.6 to 1.9 times more at risk of sustaining orofacial injury, when not making use of a mouth-guard (Sinclair, 2009). Headgear has the ability to counteract impact forces and distribute them over a larger area, while protecting bone and soft tissue structures from abrasion and injury (Sinclair, 2009). Players reported feeling much safer, were more confident, and were capable of playing with more aggression, when wearing protective headgear (Barnes *et al*., 2017). Similarly, padding was effective in reducing the incidence of minor injury, but was not effective in preventing fractures and dislocations (Sinclair, 2009). However, to gain maximum benefit from protective equipment, it must be worn correctly and consistently (Anderson & Hall, 1995; Hodgson, 1991).

Other safety considerations to bear in mind was ensuring that all competing players were at a similar level of experience, skill, and conditioning, as well as being able to pass a predetermined, rugby-specific test battery, before being considered for team selection (Mathewson & Grobbelaar, 2015). External factors, such as the condition of the rugby field, may also contribute to the risk of injury (Morkel, 2016). Therefore, if the field is properly maintained, it could assist in decreasing the number of injuries (Hillhouse, 2013; Mathewson & Grobbelaar, 2015; Morkel, 2016). Such safety strategies have positive outcomes, as players would then participate more freely in their sport with less concern for sustaining injury or losing game-time, due to injury (Mathewson & Grobbelaar, 2015). Experiencing adverse events, such as non-selection, failure within sport or sustaining injury, could influence a player's psychological and performance levels (Kruyt & Grobbelaar, 2019; Morgan, Fletcher, & Sarkar, 2015). Corrective actions taken against these adverse events could facilitate mental toughness in players and an increased resilience to overcome these adverse events, as well as overcoming injuries (Morgan *et al*., 2015).

2.4 Location, Type and Severity of Injury

Previous studies reported that amateur players experienced a higher rate of injury, but a lower severity (Swain *et al.*, 2016), although the location, mechanism and type of injury were similar in all studies (Barrett, 2015; Burger *et al.*, 2017; Mathewson & Grobbelaar, 2015). The most common type of injury was ligamentous, with the site most affected being the head and face (Swain *et al*., 2016). For four consecutive years, the most common injury locations were the head and shoulders (Starling *et al.*, 2018). The increased proportion of head and facial injuries, as well as the increased number of concussions, suggested that the impacts were around the head, implying that player contact and tackling were physically occurring too high (Puren, Barnard, & Viviers, 2007).

2.4.1 Location of Injury

In recent years, there has been an increase in the incidence and severity of shoulder injuries among rugby players, which could be attributed to the aggressive and intense nature of the sport (Lipert, Rasmus, Marczak, Kozlowski, & Jegier, 2021). Therefore, the following three playing positions and mechanisms of shoulder injury were identified: (1) the 'try scorer', because the injury commonly occurred while diving and stretching or reaching forward with the ball-carrying arm to score a try, (2) the 'tackler', because the player making the tackle was often more at risk than the opponent, and (3) the ball carrier, because of the 'direct impact' as he collided with the opponents defence and, thereby, sustained direct impact to the shoulder or fell on his shoulder (Crichton, Jones, & Funk, 2012). During match play, the injury rate for the shoulder usually increased as the match progressed, whereas Achilles tendon injuries occurred mostly in the first half, and ankle ligament injuries occurred mostly in the second half (Kaux *et al.*, 2015). Also, 58.0% of knee injuries occurred during the second half, with 32% of these being sustained in the final quarter of the match (Kaux *et al*., 2015). Out of all the injuries that occurred, players had the most absence from play, due to ACL injuries (grade 1, 2, and 3 sprains) (Whitehead, Till, Jones, Beggs, Dalton-Barron *et al*., 2021).

In the African context, the lower limb (41.2%), head and neck (26.4%) and shoulder (17.6%) were the most affected location of injury for both forwards and backs in Kenyan 1st and 2nd Division rugby (Nyagetuba, 2011). The majority (75.9%) of injury were sustained to the dominant (or right hand) side of the players (Nyagetuba, 2011). Furthermore, the ankle (17.3%), thigh (16.7%), knee and shoulder (both 15.4%) injuries were more common among male Namibian rugby players (Morkel, 2016).

2.4.2 Type of Injury

The majority of rugby-related injuries sustained invariably affected the soft tissues, as more than 50.0% of these injuries included muscular strains, ligament sprains, and contusions, and 87.0% of injuries affected the muscles, ligaments and joints collectively (Lipert *et al*., 2021).

The prevalence of injury, specifically head, shoulder and knee injuries sustained by high school rugby players were similar to those of national and international reports (Louw *et al.*, 2019). The most prevalent injuries were soft-tissue injuries, particularly muscular injuries, where players sought the help of a physiotherapist for rehabilitation (Louw *et al*., 2019). It was noted that the number of injuries increased as the season progressed, with the majority of the injuries being sprains, strains and contusions, and the lower limb was the most affected body part (Millson, 2018).

A study by Barrett (2015) on the epidemiology of injuries among Varsity Cup Koshuis rugby players at Stellenbosch University during the 2011 to 2013 seasons reported that, of the 335 injuries sustained during this period, 233 were time-loss injuries (incidents that resulted in disability and absence from sport), and 102 were serious injuries that needed medical attention. Anatomically, the most affected areas were the head, face, shoulders, and knees, with lacerations, joint injuries, concussions, and ligament injuries being the most common types of injuries recorded (Barrett, 2015).

Among elite rugby players, the incidence, severity, nature, and inciting events contributing to injury during the Rugby World Cup 2019 were similar to those reported during the 2007, 2011 and 2015 competitions (Fuller *et al.*, 2020). The most affected sites of injury were the head and posterior thigh, with the most common types of injury being muscle strains and ligament sprains, and most of these injuries occurred during specific phases of play, such as tackling, collisions and running (Fuller *et al.*, 2020). The injuries to the head and cervical spine commonly occurred during the tackle phase of play and were most frequently associated with concussions (Daly, Pearce, & Ryan, 2021; Whitehead *et al.*, 2021). Therefore, continuous exposure to physical contact sessions poses a serious concussion risk to players, which in turn can impact their cognitive function, resulting in cognitive decline and chronic traumatic encephalopathies later in life (Daly *et al.*, 2021).

Backs experienced a higher incidence of concussions than forwards, caused by high-speed tacking, which took place more frequently in open-play (Whitehead *et al.*, 2021). Research showed that players had a higher risk of sustaining concussions, if they played less than 25 matches (Rafferty *et al.*, 2019). In Rugby Football Union (RFU), about 21.0% of match-related injuries were concussions, which saw an increase in the incidence of injury for seven consecutive seasons (Chavarro-Nieto, Beaven, Gill, & Hebert-Losier, 2021). The distribution of injury were generally similar between forwards and backs in 1st and 2nd Division rugby in Kenya, as roughly 38.2% and 8.9% of injury were ligamentous and concussions, respectively (Nyagetuba, 2011).

2.4.3 Severity of Injury

The severity of an injury is determined by considering the number of days of absence, from the date of the injury until the date of the player's return to full participation in training and is available for match selection (Bahr *et al*., 2020; Brooks & Kemp, 2011; Ferreira, 2019; Fuller *et al.*, 2007). Therefore, the time (in days) absent from practice and competition is used as the basis when determining injury severity (Fuller *et al*., 2007).

A study focussing on Spanish Rugby Union players found that moderate and severe injuries were the most common types of injuries sustained by the players (35.1% and 35.4%, respectively). The least common types were mild and minor injuries (18.4% and 10.0%, respectively). During the course of the season, peripheral neurological compression, shoulder dislocation and a ruptured biceps femoris tendon were the three types of injuries (1.2%) sustained that resulted in the complete withdrawal of players from participating in the sport (Murias-lozano *et al*., 2022). Buchholtz *et al*. (2022) completed an injury surveillance study on a South African Super Rugby team, and noted the following distribution of injuries regarding the severity; 28.0% experienced a minimal (2-3 days absence) injury, 23.0% mild (4-7 days absence), 23.0% moderate (8-28 days absence) and 3.0% severe (≥ 28 days absence). Therefore, this meant that about a quarter (26.0%) of injuries sustained were severe enough to prevent players from participating for eight or more days (Buchholtz, Barnes, & Burgess, 2022). In Africa, more specifically Kenya Rugby Football Union, 32.4% and 26.5% of injuries sustained were moderate and severe, respectively (Nyagetuba, 2011). In addition, Namibian club rugby players also predominantly sustained moderate (51.8%) and severe (35.3%) injuries (Morkel, 2016).

With regard to university rugby, most injuries sustained (94 injuries; 28.1%) were of moderate severity (8-28 days absence) in the Varsity Cup Koshuis competition at Stellenbosch University (Barrett, 2015). Unfortunately, comparisons cannot be drawn between the severity of injuries in the latter study and a previous study on Varsity Cup players, as the previous study did not capture data on injury severity (Hillhouse, 2013).

2.5 Injury Occurrence Based on the Phase of Play

Rugby consists of different events, including scrums, tackles, mauls, rucks, lineouts and open play, where injuries occur in any of these phases of play. Fixed set-piece plays, such as scrums and lineouts, produced fewer injuries compared to open-play, such as tackles, running, collisions and mauls (Barrett, 2015; Viviers *et al*., 2018).

The tackle phase of play is the event that carries the highest risk of injury to both the ball-carrier and tackler (Viviers *et al*., 2018). More specifically, the following situations were more likely to cause and place players at higher risk of head injury, namely, exposure to high-velocity tackles, the upright body position of the tackler, a higher point of contact, unsighted tackles, tackles made off-balance, front-on tackles and high collision forces (Gardner, Iverson, Edwards, & Tucker, 2021; Rafferty *et al*., 2017).

Ball carrying and tackling techniques are key risk factors for head injury, especially when the tackler does not move into a lower body position, which decreases the chances of head-to-head collisions (Martin *et al*., 2021). Previous literature showed that the ball-carrier had a higher incidence of injury than the tackler, and that the injury severity was twice that of the tackler, suggesting that the focus should be on implementing better ball-carrying skills and attacking tactics that were safe and effective (Posthumus, 2008). Therefore, when modifying the risk of head injury, it is important to consider the body position of both the ball-carrier and tackler, and the methods that the ball-carrier uses to evade contact (Gardner *et al*., 2021). A player dominating or evading contact, while positioning his body in the direction of the support, is described as having an effective and successful method of ball-carrying (Posthumus, 2008).

Sobue *et al.* (2018) focused on whether the tackler's head position, relative to the ball-carrier, was highly correlated with head and neck injuries in rugby. Incorrect head position during tackles was accompanied by concussions, neck injuries, stingers and nasal fractures (Sobue *et al*., 2018). Fewer safety steps were taken before making contact that also contributed to injury (Sobue *et al.*, 2018).

Similarly, shoulder tackles were safer for tacklers in comparison to arm only tackles, while injuries were less likely to occur, when the ball-carrier was aware of the oncoming defender or when attempting to fend- or hand-off the defender (Burger *et al*., 2017). For both the ball-carrier and tackler, injuries were less likely to occur when initial contact was made to the shoulder region of the tackler, instead of their head and neck (Burger *et al*., 2017).

Mathewson and Grobbelaar (2015) focused on tackle-injury epidemiology in hostel rugby players at Stellenbosch University, which spanned over two hostel rugby seasons (2012 - 2013). The tackle was the most dangerous phase of play, leading to 61.0% of all injuries, with the tackler being more at risk than the ball-carrier. Injuries to the face were most prevalent, with lacerations being the most frequent type of injury, and the ball-carrier sustaining most of the injuries to the head (Mathewson & Grobbelaar, 2015). In recent years, there has been a steady increase in shoulder injuries during the tackle, with front-on tackling being the main injury mechanism that affected the tackler (Starling *et al*., 2018). During the tackling phase of play, the tackler experienced more injuries to the upper limbs (35.0%), with 28.0% affecting the shoulder girdle, head, neck and face, whereas, the player being tackled was affected more in the lower limbs (Posthumus, 2008; Starling *et al*., 2018).

Regarding phase of play, the tackle phase was the most prominent for injury, followed by mauls and rucks, with 13.0% of these injuries due to foul play (Bird, Waller, Marshall, Alsop, Chalmers *et al*., 1998). In the injury surveillance study at the 2019 Rugby World Cup in Japan, injuries occurred mainly during tackling, collisions and running (Fuller *et al.*, 2020).

A tackled player is associated with a higher number of ligamentous-knee and shoulder instability injuries that were attributed to the high frequency of contact, the speed at which impact occurred, and the dynamic nature and rotational torque experienced at joints during the contact event (Whitehead *et al*., 2021). The tackler was placed at greater risk of sustaining injury, when they feared contact or approached contact 'half-heartedly' (Posthumus, 2008). The differences in impact forces between the ball-carrier and the tackler were shown to be risk factors for injury, especially for the player with the lowest momentum going into the tackle (Posthumus, 2008).

The increased prevalence of injuries during the tackle and ruck phases of play, over the years, has been attributed to the increased number of these events during game play (Roberts *et al*., 2013). Although other events, such as rucks and mauls (15.0 - 36.0%), running and evading contact (10.0%) and scrum engagement (1.0 - 7.0%), carried a lower risk of injury, however, these injuries were often more severe (Kaux *et al*., 2015). In contrast, a relatively lower incidence of injury occurred during scrums and line-outs when lower impact speeds were used, and players were able to position themselves correctly before contact (Roberts *et al*., 2013).

The lineout phase of play had a low-risk incidence of injury per player-hours and per event compared to the other phases of play (Fuller *et al*., 2007; Posthumus, 2008).

Fuller *et al*. (2007) found that the scrum had a 60.0% greater risk of injury than the tackle, which frequently affected the front row players (hooker and props) in more than 80.0% of cases. This phase of play also induced the most catastrophic cervical injuries, as 40.0% of spinal cord injuries were attributed to the scrum (Kaux *et al*., 2015; Posthumus, 2008). These injuries usually occurred when the force of impact during the scrum was greater than the threshold of tolerance of the spine (Posthumus, 2008). Therefore, good scrummaging technique should be enforced to ensure that players had appropriate alignment of the head, neck, and trunk, and that the posterior muscles of the back, shoulders, and neck had adequate strength to maintain a safe body position, both before and during scrum engagement (Posthumus, 2008).

2.6 Injury Occurrence Based on the Playing Position

The playing positions in a 15-man team of Rugby Union are grouped into forwards and backline players, and further subdivided into 6 groups, namely, the front row, second row, back row, scrum halves, inside backs and outside backs (Figure 2.2) (Roberts *et al.*, 2013).

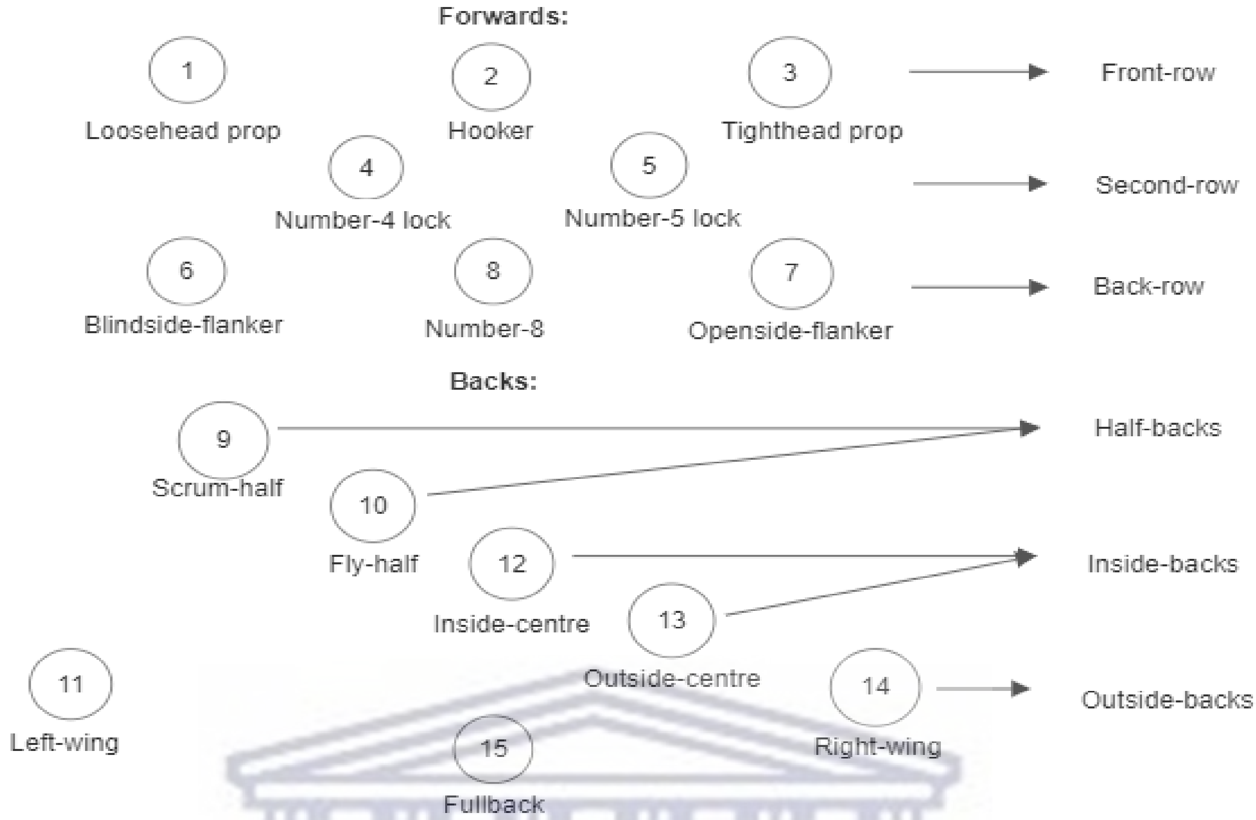

Figure 2.2: Rugby Union 15-man team formation.

The medical staff should understand the risk associated with the various playing positions, especially in the various phases of play, such as the tackle, scrum, and line-out, when players contest for the ball (Kaplan *et al*., 2008; MacQueen & Dexter, 2010). The different rates and patterns of injury are the result of the different workloads, movement patterns, and reactive movements per playing position (Villa, Mandelbaun, & Lemak, 2018). The forwards were generally bigger in size and involved in more contact events, such as scrums, lineouts, rucks and mauls, while the backs were smaller and tended to be more agile and faster, as they were required to engage in more running and open game-play (Kaplan *et al*., 2008). Usually, the forwards focused on gaining territorial advantage through ball-carrying and collisions in game-play, while the backs used their ball-handling, accurate passing, pinpoint kicking, and speed tactics to advance against the opponents (Donkin *et al*., 2020).

Although research has commonly grouped rugby positions into forwards and backs, more position-specific or individualised approaches can be followed, as each position is exposed to different workloads and events during game-play, resulting in a variety of injury profiles (Brooks & Kemp, 2011; Ogaki *et al*., 2020). The different methods of reporting injury incidence per playing position has led to difficulty in making comparisons, but some trends can still be identified (Kara, 2013). By utilizing technology, such as GPS, more information regarding playing position was gathered, which allowed for comparisons between playing positions, enabling coaches to assess competitive performances through the effective grouping of players (Cunningham, Shearer, Drawer, Eager, Taylor *et al.*, 2016). Based on the extensive feedback from injury profiles and technologies used in the sport, as well as the characteristics of the various playing positions, different preventative measures and exercises can be developed and implemented for each playing position (Kara, 2013; Ogaki *et al*., 2020).

In the New Zealand Rugby Injury and Performance Project, injuries occurred more frequently in matches than practices, with male players at higher risk than females (Bird *et al.,* 1998). Male locks and female inside backs were the most injury-prone playing positions, with the lower limbs being the most injured body region for both male and female players, and ligamentous sprains the most common type of injury sustained (Bird *et al.,* 1998). The 2003 RWC Injury Surveillance Project found that the back row or loose forwards (flankers and eighth men), sustained the most injuries, with most of the injuries to both backs and forwards occurring during the second-half of the match (Fuller *et al*., 2020; MacQueen & Dexter, 2010).

Tondelli (2020) found that injuries, such as ankle sprains and anterior cruciate ligament ruptures, were experienced more among the forwards, while hamstring injuries were more prevalent among the backs. Roberts *et al*. (2013) found that 80.0% of injuries were caused by contact events, with 50.0% caused by the tackle phase of play. The most common non-contact injury was running, where more than 50.0% of these injuries affected the hamstrings (Roberts *et al*., 2013). There was a significant association between the incidence of injury and the position of the player, as well as the incidence of injury and the phase of play, with the position at highest risk being the flanker (McManus & Cross, 2004).

Front row forwards were predisposed to cervical injuries, usually caused by the impact forces when engaging the scrum, that resulted in a longer period of absence compared to other playing positions (Brooks & Kemp, 2011). In addition, tight- and loose-head props and hookers sustained similar injury profiles and were at greater risk for sustaining catastrophic cervical injuries than other playing positions (Posthumus, 2008).

Some literature indicated that the second row sustained more injuries, while the halfbacks and inside centres exhibited lower rates of injury, although the halfbacks were at higher risk of sustaining concussions than forwards and backs (Chéradame *et al*., 2021). Other research showed that open-side flankers and locks sustained the most severe injuries, while the hooker and fly half experienced a higher injury rate than other positions (Gabbett, 2016; Kaux *et al*., 2015). When looking at the run-ons or substitute players, then the props, flankers, wings, and centres were the most substituted positions due to injury (Kaux *et al*., 2015; Roux, Goedeke, Visser, van Zyl, & Noakes, 1987). The tight five and outside back players were 12.8 and 9.6 times more likely to sustain recurring injuries, respectively, than midfield backs (Pasqualini *et al*., 2021).

At Super Rugby level, over a period of five seasons, the inside and midfield backs sustained the lowest number of injuries compared to the tight forwards who sustained the highest (Kara, 2013). The midfield backs played in a high-impact position and was, thereby, exposed to a greater risk of sustaining contact injuries, while non-contact injuries were most likely to be sustained by outside backs (Kara, 2013).

2.7 Predicting the Risk of Injury Based on the Playing Position

Most studies used linear or logistic regression analyses to explain rugby injury data (Johnson, Tranaeus, & Ivarsson, 2014). The use of a logistic regression model can predict the relative risk of an outcome on the basis of multiple independent variables (Hewett, 2017). To determine the risk of future injuries, one has to prospectively investigate the relationship between risk factors and possible outcome variables (Hewett, 2017). In sport, negative binomial and ordinal regression models are used to record the duration of recovery and analyse the influence of different injury-related variables (Kampakis, 2016). This information is then processed through machine learning algorithms to produce a predictive model (Kampakis, 2016). In terms of injury prediction, an accurate prediction of a recurring injury was a first-time injury (Hewett, 2017).

A logistic regression completed by Bjelanovic *et al.* (2023) found a higher risk of injury amongst the front and second row forwards (OR = 3.5, 95% CI: 1.1 to 11.3 and OR = 5.0; 95% CI: 1.6 to 15.6, respectively) and centres (OR = 4.7, 95% CI: 1.2 to 14.3). In addition, a pre-season injury (OR = 1.3, 95% CI: 1.0 to 1.5), playing at a higher level of the competition (OR = 1.4, 95% CI: 1.1 to 1.7), and players with higher body mass (OR = 1.0, 95% CI: 1.0 to 1.0) were identified as potential predictors of injury (Bjelanovic, Mijatovic, Sekulic, Modric, Kesic *et al.*, 2023).

Using these models enable the medical staff to make informed decisions on training and player welfare based on scientific evidence (Gabbett, 2010). Analysing and interpreting data on match and training loads helps to ensure that players are within 'safe' or 'acceptable' limits of injury risk (Gabbett, 2010). However, due to the complex nature of intrinsic and extrinsic risk factors, there is much difficulty in attempting to predict the occurrence of injury (Gabbett, 2010). Therefore, the use of predictive modelling should aim to identify the risk of injury in order to implement strategies to mitigate this risk at an individual level (Van Eetvelde, Mendonça, Lei, Seil, & Tischer, 2021). Comparisons can then be drawn between predicted and actual injury data to assess the accuracy of the model (O'Donoghue, Paul, Eustace, McFarlan, & Nisotaki, 2016).

There are no injury surveillance studies investigating the epidemiology of injuries sustained during the FNB Varsity Cup Young Guns tournament, despite the high risk of injury associated with Rugby Union (Oudshoorn *et al*., 2017). Moreover, there is a lack of scientific evidence regarding the incidence and characteristics of injuries among the Young Guns cohort (Falkenmire *et al*., 2020; Hillhouse, 2013; Murias-lozano *et al*., 2022).

CHAPTER THREE: RESEARCH METHODS

3.1 Introduction

The aim of the study was to determine the incidence and the risk factors of injury among male rugby players participating in the FNB Varsity Cup Young Guns tournament, as well as to predict the risk of injury based on playing position. Chapter three describes how the aims and objectives of the study were addressed, as well as the study design and study procedures. The chapter explains how participant recruitment was conducted, the research procedures followed, as well as the statistical analysis of the data and the ethical considerations.

3.2 Research Design

This study followed a quantitative, non-experimental, and cross-sectional research design that included both correlation and regression analysis.

3.3 Research Setting

The FNB Varsity Cup Young Guns tournament for 2022 took place at ten tertiary institutions across South Africa. The competing teams were from Cape Town (the University of the Western Cape and the University of Cape Town), Pretoria (the University of Pretoria), Johannesburg (the University of the Witwatersrand and the University of Johannesburg), Stellenbosch (the University of Stellenbosch), Gqeberha (Nelson Mandela University), Bloemfontein (the Central University of Technology and the University of the Free State) and

Potchefstroom (North West University). The competition started on 14 March 2022 and lasted for seven weeks, with games being played every Monday evening. The necessary injury data was collected by the team's physiotherapist at each tertiary institution.

3.4 Population and Sampling of Participants

The population for the study was the ten male Young Guns rugby teams taking part in the FNB Varsity Cup tournament in the 2022 rugby season. According to the tournament regulations, the players were registered students at their respective universities, and from the age of 18 to 20 years. Each team of players at each institution consisted of approximately 36 players, thereby, giving a total study population of approximately 360 (36 players x 10 teams) rugby players. The conveniently recruited study sample included all 10 teams that comprised the study population. However, only 7 of the 10 participating teams agreed to participate in the study, resulting in a total sample size of approximately 252 (36 players x 7 teams) participants, all of whom met the inclusion criteria.

3.5 Delimitations of the Study

3.5.1 Inclusion Criteria

The following inclusion criteria were applied in the study, namely, that the participants in the study had to be a:

- Registered student.
- Fully COVID-19 vaccinated player.
- Male rugby player aged 18 to 20 years.

- Player for their university's Varsity Cup Young Guns team for the 2022 tournament.

3.5.2 Exclusion Criteria

The following exclusion criteria applied to the study:

- A player who did not comply with any of the competition rules set by the Varsity Cup.
- A player who was injured and not eligible for team selection.

3.6 Data Collection Procedures

3.6.1 Strengthening the Reporting of Observational Studies in Epidemiology - Sports Injury and Illness Surveillance (STROBE-SIIS) Guidelines

The STROBE-SIIS guidelines (Appendix G) were introduced to help researchers in formulating a desired protocol, when conducting an injury surveillance study in order to ensure that high-quality reports were produced (Bahr *et al*., 2020; Cuschieri, 2019). The guidelines are provided for cohort, case-control, and cross-sectional studies (Bahr *et al*., 2020). Use of the STROBE-SIIS allows other researchers to easily reproduce and draw comparisons across different studies (Bahr *et al*., 2020).

3.6.2 Research Instrument

An adapted version of the consensus statement for the injury surveillance questionnaire (Rugby Injury Consensus Group Injury Report Form for Rugby Union) was used to record the players' injury data. The definitions used in this instrument were also used and aligned with the International Olympic Committee (IOC) consensus statement and STROBE-SIIS guidelines.

These documents were included in order to ensure consistency with regard to the definitions and methods used in previous research, so as to enable inter-sport injury comparisons (Bahr *et al*., 2020).

Some of the data collected from the questionnaire included the player's date of injury and return to participation (to determine severity), playing position (whether backs or forwards), and the site and time of injury (whether during a match or training).

3.6.3 Reliability and Validity

The reliability of an instrument refers to whether the instrument is clear of error (Warren, Lininger, Chimera, & Smith, 2018). This standardized, validated and adapted version of the injury surveillance questionnaire was used to allow for consistent and comparable results from rugby union competitions (Mathewson & Grobbelaar, 2015).

The validity of an instrument refers to the degree to which the instrument measures the construct intended (Warren *et al*., 2018). Face and content validity evaluate a data extraction tool to ensure the tool includes all relevant questions, and eliminates undesirable information (Taherdoost, 2018). It follows a judgemental approach to establish content validity, which involves reviewing literature and iterative meetings by experts or panels. The procedure followed required both researchers and experts to be present to facilitate validation (Taherdoost, 2018). The fact that the questionnaire was a widely accepted tool for injury data collection confirmed and provided evidence of the tool's face validity**.** Content validity of an instrument indicates how well the extraction tool captures all necessary aspects of a construct (Warren *et al.,* 2018). The presence and input of multiple experts into the consensus documents confirmed its content validity (Warren *et al*., 2018). Being widely accepted and used at the elite level confirmed the content validity of the questionnaire (Warren *et al*., 2018).

A Rugby Injury Consensus Group (RICG) was initiated by the International Rugby Board (IRB) Medical Advisory Committee to develop a consensus statement that would be suitable for Rugby Union (Fuller *et al*., 2007). Procedures and definitions in this document were then presented to the RICG group consisting of seven voting members, who then agreed on a finalized document, which was later approved by the International Rugby Board Council (Fuller *et al*., 2007). The questionnaire, approved by the International Rugby Board (IRB) Council, defined various terms, such as injury and mechanism, as well as classified injuries into severity, type and location. The 98% reliability agreement on the quality of the questionnaire allowed for confident use of the tool for data collection in prospective studies. A team of expert advisors updated the recommendations for capturing injury and illness data in rugby, and accepted the definitions of the International Rugby Board's Rugby Injury Consensus Group into the International Olympic Committee Consensus Statement (Bahr *et al.*, 2020). This is applicable to both SARU and the BokSmart programme, thereby, providing further evidence of the reliability and validity of the questionnaire (Bahr *et al.*, 2020; BokSmart, 2020).

Only a few studies to-date have determined the validity and/or reliability of injury surveillance systems utilized in sports research (McManus, 2000). The precision and reproducibility of the data obtained in an epidemiological study determines the quality of the results. Therefore, it is crucial to understand the validity and reliability of the research instrument used for data extraction, before capturing and interpreting the results (Bjørneboe *et al*., 2011).

To ensure the reliability of the original injury report form, the definitions were tested and approved by experienced raters, such as the IRBs Chief Medical Officer, and six representatives from different national rugby unions in both the northern and southern hemispheres, who formed the Rugby Injury Consensus Group (RICG) (Fuller *et al.*, 2007).

Non-voting representatives who had experience in studying injuries in a variety of team sports were recruited to provide the panel with a broader perspective and better knowledge of the process (Fuller *et al*., 2007). Many studies have also made use of these consensus statements, confirming that they can be used to consistently record injuries within Rugby Union (Warren *et al*., 2018). The definitions and procedures were aligned with the consensus statement on definitions and data collection for injuries in Rugby Union, and these exact procedures were used in the research completed in the 2007, 2011, 2015, and 2019 RWC injury surveillance studies (Fuller *et al*., 2020).

Virtual and telephonic meetings were held to ensure the physiotherapist recording the injury data knew how to utilize the form. These individuals were familiar with certain medical terms, such as a sprain, contusion, etc., used in the injury questionnaire. These steps were followed to ensure that the research data was reported and recorded accurately.

3.6.4 Steps Followed for Data Collection

Permission to conduct the study was sought from the Director of the FNB Varsity Cup Rugby tournament, who duly notified the head of rugby at each institution. A virtual meeting was attended by each team's physiotherapist, which served as training on how to complete the data collection instrument. All physiotherapists collected the data, for the duration of the competition between the 14th of March and the 25th of April 2022, by means of the rugby injury questionnaire, which is used widely to record injuries sustained within Rugby Union (Fuller *et al*., 2007).

Sociodemographic information, such as age, weight, height, playing position, and health-related physical fitness components were captured prior to the competition. The specific injury data was then collected at each practice session and/or competitive match for the duration of the 2022 FNB Varsity Cup tournament. All information was later captured onto an MS Excel spreadsheet, specific to the study outcomes.

The study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines, while the definitions used were aligned with the consensus statement on injury definitions and data collection procedures for studies of injuries in Rugby Union and the IOC consensus document (Bahr *et al*., 2020; Fuller *et al*., 2007; Toohey, Drew, Finch, Cook, & Fortington, 2019).

Injuries were defined as any physical complaint, sustained through an energy transfer that exceeded the body's natural ability to maintain either its structure or function. These were sustained, while participating either in training or competition, regardless of whether they were considered for medical attention or time-loss (Fuller *et al*., 2007; Toohey *et al*., 2019).

Injuries were sub-categorized into medical attention and time-loss injuries (Figure 3.1). Injury resulting in a player receiving medical attention was referred to as a medical-attention injury, while time-loss injury referred to injury resulting in a player being unable to participate in training and/or competition (Fuller *et al*., 2007; Toohey *et al*., 2019). A new injury was considered the first occurrence of an injury, whereas an injury was considered to be recurrent if the same injury was sustained to the same site (Bahr *et al*., 2020; BokSmart, 2020; Fuller *et al*., 2007).

The number of days absent from rugby was counted from the day after the onset of injury, until the day before the player returned to training and competition (Bahr *et al*., 2020; BokSmart, 2020). The medical team at each institution diagnosed the severity of injury, according to the consensus statement recommendations: 0–1 days (slight), 2–3 days (minimal), 4–7 days (mild), 8–28 days (moderate), and more than 28 days (severe) that sometimes was "career-ending" and "non-fatal catastrophic" injury (Fuller *et al*., 2007; Starling *et al*., 2021).

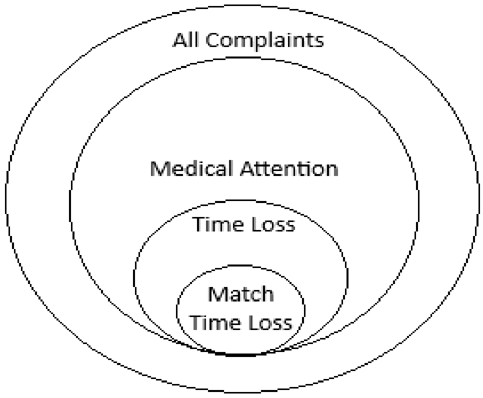

Figure 3.1: Interactions between definitions of injury and illness (Clarsen & Bahr, 2014).

The player's position, date of injury, time of injury (whether during a match or training), and the date of return to full sport participation (to determine injury severity) were some of the research data that was recorded. The site, type and mechanism of injury were also included, as well as the phase of training or match in which injury occurred. To ensure accurate and complete injury data, the proposed classifications for mechanisms of injury were: tackled, tackling, ruck, other player collision, scrum, line-out, and maul (for direct and indirect contact events) and stepping, running and kicking (for non-contact events) (Ogaki, Nariai, Otake, Ogura, Murakami *et al.*, 2022). Injuries not known to the player or medical staff were recorded as "unknown", while rarely occurring events were listed as "other". According to the Rugby Union injury reporting consensus guidelines, the injuries sustained should be categorized into specific body regions (Bahr *et al.*, 2020; Toohey *et al.*, 2019).

In addition, the following questions (and potential answers) were included on the adapted version of the form:

a. In which period of the game did the injury occur?

   [During a match: 1st quarter, 2nd quarter, 3rd quarter, 4th quarter or during a training session.]

b. Were you wearing/using any protective equipment?

   [Yes □ or No □.]

c. Were you using any of the following protective equipment?

   [Mouth-guard □, head-gear □, shoulder padding □ or no other protective equipment □.]

d. In which part of the field did the injury occur?

   [Opposition-22 □, own-22 □, between opposition-22 and halfway line □, between own-22 and halfway line □ or in-goal area □.]

e. Was the player in the starting 15 or came on as a substitute?

   [In starting 15: Yes □ or No □.]

   [Player came on as a substitute: Yes □ or No □.]

With the current study being prospective in nature, it minimized the risk of recall bias. Although this error was still possible in a prospective cohort study, nevertheless, both the follow-up and recording period for the injury information were completed shortly after the injury occurred. This was done to ensure that the data was reported and recorded accurately and consistently (Sedgwick, 2013).

Regarding the player's physical fitness testing, the Yo-Yo is commonly used to determine a player's aerobic power (i.e., oxygen uptake during dynamic exercise), as it provides an indirect measure of the physically fit intermittent team-sport athletes are (Blair, Cronin, Rehrer, Button, & Gill, 2018; Sant'Anna, Roberts, Moore, Kraak, & Stokes, 2023). Furthermore, the Bronco test was used to determine the maximal aerobic running speed (Deuchrass, Smith, Elliot, Lizamore, & Hamlin, 2019; Sant'Anna *et al*., 2023).

The Yo-Yo test, controlled by audio signals, required players to complete repeated 2×20 meter shuttles at a progressively increasing speed that included an active rest of 10 seconds (or jog for 2.5 meters) between each shuttle. When players were unable to reach the finish line before the audio signal, the test was then terminated and the highest level completed by the player was recorded (Bangsbo, Iaia, & Krustrup, 2008; Sant'Anna *et al*., 2023).

The Bronco test was administered by measuring, marking and placing cones at the 0, 20, 40, and 60-meter lines. The players were then instructed to run from the 0 meter line to the 20 meter line and back, then from the 0 meter line to the 40 meter line and back, and lastly from the 0 meter line to the 60 meter line and back. This entire sequence is counted as one repetition, and therefore, in order to achieve 1200 meters, players were required to complete five repetitions as fast as possible (Kelly, Jackson & Wood, 2014; Sant'Anna *et al*., 2023).

3.7 Statistical Analysis

The research data was entered into a Microsoft Office Excel 2016 spreadsheet using a double-entry format and cleared of any errors. To ensure confidentiality and anonymity, any identifiers, such as the names of players and their identity numbers were removed, during the data coding process. The data was stored electronically on a password-protected computer file, to which only the researcher and research supervisor had access. The Statistical Package for the Social Sciences (SPSS) Version 28 was used for data analysis. Descriptive statistical analysis (percentages, means, and standard deviations) and inferential statistics (Pearson's Chi-square test, Mann-Whitney U-test, Kruskal-Wallis H-test, and multinomial regression analysis) were performed.

The Pearson's Chi-square test was used to determine statistically significant associations between categories (e.g., forwards and backs and the types of injuries sustained). The differences in sociodemographic and anthropometric data between playing groups were analysed using the Mann-Whitney U-test and the Kruskal-Wallis H-test. Multinomial logistic regression analysis was used to predict the risk of injury based on playing position. A significance level of $p < 0.05$ was used to indicate statistical significance.

The following calculations were used to determine injury rate in the study (Bahr *et al*., 2020; BokSmart, 2020; Fuller *et al*., 2007; Toohey *et al*., 2019):

- Total match exposure time: i.e., total number of hours

  Number of matches played X number of players in the team X duration of the match ÷ 60.

- Total injury incidence rate: i.e., number of injuries / 1000 hours

  Number of injuries ÷ exposure in hours X 1000.

- Match injury incidence rates: i.e., number of injuries / 1000 hours

  Number of match injuries ÷ match exposure in hours X 1000.

- Training injury incidence rates: i.e., number of injuries / 1000 hours

  Number of training injuries ÷ training exposure in hours X 1000.

3.8 Ethics Considerations

Ethics clearance was obtained from the Biomedical Research Ethics Committee (BMREC) at the University of the Western Cape (Ethics Registration Number: BM21/5/15), before commencement of the study (Appendix D).

Each participant received an information sheet (Appendix A) detailing the scope of the study, as well as the risks and benefits. Prior to the collection of data, participants completed an informed consent form (Appendix B) in writing, which stated that participation in the study was voluntary with the right to withdraw at any time without any negative consequences. The data on the players was captured by means of the injury report form (Appendix C) and recorded anonymously onto a spreadsheet. Identifiers, such as the players' names and identity numbers were removed during the data coding process to ensure confidentiality and anonymity. A formal letter, stating the nature of the study, was communicated to the Director of Varsity Sport in order to obtain permission to conduct the study and to gain access to the student-athletes (Appendix E).

Only the researcher and study supervisors had access to the recorded data, which was stored electronically in an encrypted file in the university research repository. This data will be stored for a period of 5 years after the study has been completed, before being destroyed. If the research is published, the participants' personal information will remain confidential.

CHAPTER FOUR: RESULTS

4.1 Introduction

The purpose of this chapter is to present the results of the research, with an interpretation of the data analysis that is presented in tabulated or graphical formats. The study aimed to address the incidence and risk factors of injury, while predicting the risk of injury based on playing position among FNB Varsity Cup Young Guns players. The results initially express descriptive statistics of the participants, specifically, player demographics, anthropometric data and aerobic fitness test scores. The incidence, location, type and severity of injury were also determined, including information on the use of protective equipment, the phase of play in which the injury occurred and the part of the field in which the injury was sustained. Inferential statistics were also used to determine significant differences between groups and correlations, as well as predict the risk of injury based on playing position through multinomial logistic regression analysis.

Only seven teams (70.0%) of the ten teams indicated that they were willing to participate in the study. Therefore, the injury data of the seven teams was collected and subjected to analysis.

From the three teams that declined participating in the study, one team indicated that they did not have the relevant personnel to assist with collecting injury data, whereas the remaining two teams were not willing to share their player information and, thereby, were excluded from the study.

From the seven participating teams, one team indicated that they did not collect any anthropometric data for their players, but were able to submit the injury data.

4.2 Anthropometric Characteristics of the Players

The anthropometric results of a total of 205 players (107 forwards and 98 backs) is reported in Table 4.1. The anthropometric characteristics of the players is based on their playing position. The mean age of the male players was 18.8 ± 0.7 years (forwards: 18.8 ± 0.6; backs: 18.8 ± 0.7 years). The age range of the players was between 18 and 20 years. The mean stature of the players was 180.6 ± 7.4 cm (forwards: 183.4 ± 6.9; backs: 177.5 ± 6.7 cm), with the range between 160.0 and 197.0 cm. The mean body mass of the players was 91.7 ± 14.5 kg (forwards: 100.9 ± 12.3; backs: 81.7 ± 9.0 kg), ranging between 65.0 and 144.7 kg. The mean body mass for forwards and backs was 100.9 and 81.7 kg, respectively, and was statistically significant (U = 816.0; p = 0.004) (Figure 4.1).

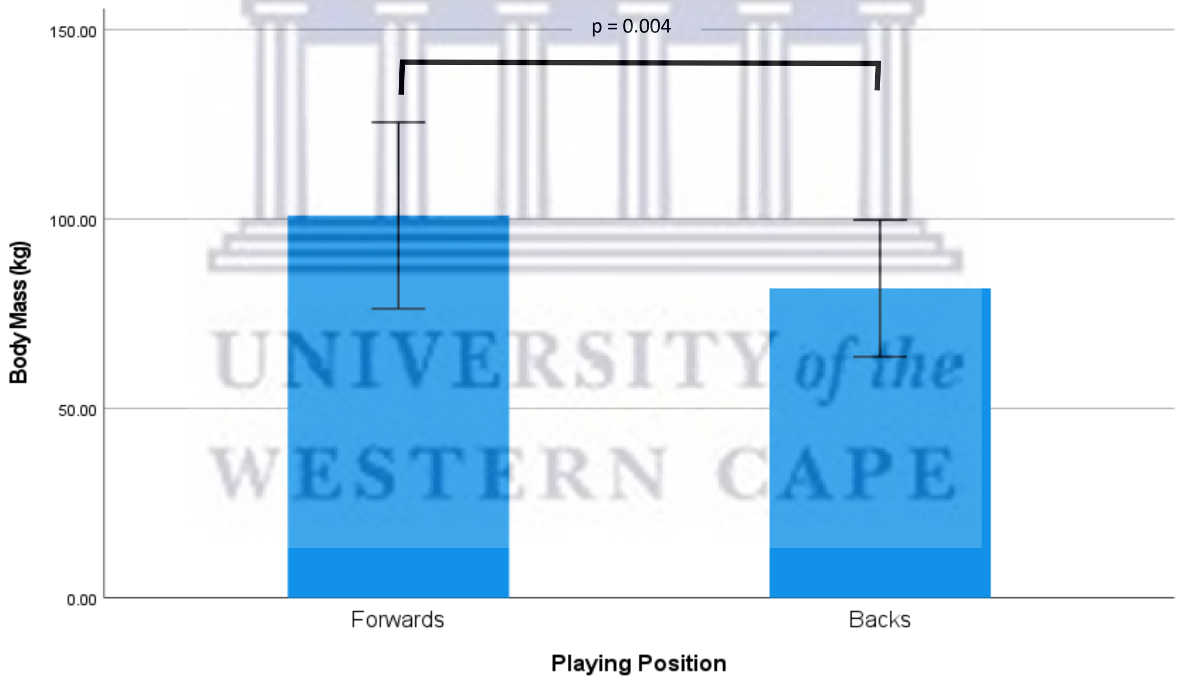

Figure 4.1: Statistically significant difference in body mass between playing groups.

However, no statistical difference was found in stature between forwards and backs (U = 2506.0; p = 0.119). Statistically significant differences were found for the body mass of the front and second rows (U = 382.5; p = 0.020), the second and back rows (U = 301.0; p = 0.029) and the stature of inside and outside backs (U = 288.5; p = 0.046).

Table 4.1: Comparison of the anthropometric characteristics of the 2022 Young Guns players based on the playing position.

Playing Position (Player subgroups)	**Age** (years)	**Stature** (cm)	**Body mass** (kg)
		Mean (standard deviation)	
All players (n = 205)	18.8 (0.7)	180.6 (7.4)	91.7 (14.5)
Forwards (n = 107)	18.8 (0.6)	183.4 (7.0)	100.9 (12.3)*
Front row (n = 46)	18.7 (0.6)	180.8 (6.0)	107.3 (14.0)
Second row (n = 25)	18.8 (0.7)	190.8 (3.8)	99.0 (7.1)**
Back row (n = 36)	19.0 (0.6)	181.5 (6.2)	94.1 (8.3)
Backs (n = 98)	18.8 (0.7)	177.5 (6.7)	81.7 (9.0)
Halves (n = 35)	18.8 (0.6)	176.4 (7.2)	79.8 (10.2)
Inside backs (n = 35)	18.8 (0.6)	179.7 (5.7)**	85.7 (7.2)
Outside backs (n = 28)	18.9 (0.7)	176.2 (6.8)	79.0 (8.0)
p value	< 0.901	< 0.001	< 0.001

Note: * indicates statistically significant difference between forwards and backs p < 0.05.
** indicates statistically significant difference between subgroups p < 0.01.

Table 4.2 compares the normative data of the SA National Under-21 players to the Young Guns players based on playing position. The Young Guns forwards and backs were within the range of the norms of the national players in terms of stature and body mass. The mean body mass results of the Young Guns back row and inside backs (94.1 and 85.7 kg, respectively) were slightly higher than that of the normative data (93.3 and 82.5 kg, respectively).

Table 4.2: Comparison of the anthropometric characteristics between the 2022 Young Guns players and the normative data of the SA National Under-21 players based on the playing position.

Playing Position (Player subgroups)	**Stature** (cm)	**U-21 Norms** (cm)	**Body mass** (kg)	**U-21 Norms** (kg)
	Mean (standard deviation)			
All players (n = 205)	180.6 (7.4)	182.0 (7.6)	91.7 (14.5)	94.3 (12.5)
Forwards (n = 107)	183.4 (7.0)	184.8 (8.2)	100.9 (12.3)	101.0 (9.0)
Front row (n = 46)	180.8 (6.1)	181.8 (6.1)	107.3 (14.0)	110.2 (9.9)
Second row (n = 25)	190.8 (3.8)	196.6 (5.0)	99.0 (7.1)	107.3 (5.2)
Back row (n = 36)	181.5 (6.2)	183.5 (6.1)	94.1 (8.3)	93.3 (8.3)
Backs (n = 98)	177.5 (6.7)	176.7 (0.71)	81.7 (9.0)	80.9 (2.1)
Halves (n = 35)	176.4 (7.2)	177.2 (7.1)	79.8 (10.2)	82.5 (10.3)
Inside backs (n = 35)	179.7 (5.7)	177.2 (7.1)	85.7 (7.3)	82.5 (10.3)
Outside backs (n = 28)	176.2 (6.8)	176.2 (5.4)	79.0 (8.0)	79.4 (7.7)

Table 4.3 describes the mean scores of the two aerobic fitness tests for each playing position. Overall, the forwards produced slower mean scores for the Bronco test (5.5 minutes) in comparison to the backs (4.6 minutes). More specifically, the props scored the slowest mean scores for the Bronco test (6.1 minutes), with the best times achieved by the number 8 (4.8 minutes) for the Bronco test. Among the forwards, the props also produced the lowest Yo-Yo test score (level 14.1), while the locks achieved the highest score in the Yo-Yo test (level 16.1). Among the backs, the fullback position averaged the best time overall (3.8 minutes) for the Bronco test, while the half back position produced the best results for the Yo-Yo test (level 17.4).

Table 4.3: Test results for the three aerobic fitness tests of the 2022 Young Guns players based on the playing position.

Playing Position (Player subgroups)	**Bronco Test** (minutes)	**Yo-Yo Test** (level)
	Mean (standard deviation)	
All players (n = 205)	4.8 (1.0)	15.8 (1.4)
Forwards (n = 107)	5.5 (1.1)	15.2 (1.3)
Props (n = 33)	6.1 (1.4)	14.1 (1.2)
Hooker (n = 13)	5.6 (0.9)	14.5 (0.7)
Locks (n = 25)	5.9 (0.7)	16.1 (1.0)
Blindside flanker (n = 13)	4.9 (1.0)	15.7 (1.3)
Openside flanker (n= 14)	5.4 (1.2)	15.4 (1.0)
Number 8 (n = 9)	4.8 (0.9)	15.2 (1.0)
Backs (n = 98)	4.6 (0.8)	16.8 (0.9)
Half back (n = 17)	4.7 (0.9)	17.4 (0.8)
Flyhalf (n = 18)	4.7 (0.7)	16.8 (0.3)
Inside centre (n = 16)	5.0 (0.7)	17.1 (1.4)
Outside centre (n = 19)	4.6 (0.5)	16.5 (0.6)
Wingers (n = 16)	4.8 (0.9)	16.3 (1.0)
Full back (n = 12)	3.8 (0.6)	16.7 (0.8)
p value	< 0.278	< 0.112

Table 4.4 compares the reference data of professional rugby players to that of the Young Guns players. Overall, only 29.7% of forwards were below the prescribed Bronco test norms, with the number 8 position producing the best result. Most surprisingly, 48.7% of the backs were below the Bronco norms, but produced better results than the forwards. The fly half, outside centre and fullback positions were all below the prescribed norms for the Bronco test. Furthermore, both the forwards and backs were able to score below or within the norms for the Yo-Yo test.

Table 4.4: Comparison of the aerobic fitness test scores between the 2022 Young Guns players and the reference data of professional rugby players based on the playing position.

Playing Position	Bronco Test		Yo-Yo	
	Young Guns (minutes)	**Reference Score** (minutes)	**Young Guns** (level)	**Reference Score** (level)
	Mean			
Props	6.1	< 5.3	14.1	> 16.0
Hooker	5.6	< 5.0	14.5	> 18.0
Locks	5.9	< 5.2	16.1	> 17.0
Blindside flanker	4.9	< 4.9	15.7	> 18.0
Openside flanker	5.4	< 4.8	15.4	> 19.0
Number 8	4.8	< 4.9	15.2	> 18.0
Half back	4.7	< 4.7	17.4	> 19.0
Flyhalf	4.7	< 4.8	16.8	> 18.0
Inside centre	5.0	< 4.8	17.1	> 18.0
Outside centre	4.6	< 4.8	16.5	> 18.0
Wingers	4.8	< 4.8	16.3	> 18.0
Full back	3.8	< 4.8	16.7	> 19.0

4.3 Injury Incidence During Training and Matches

All teams submitted match and training exposure hours, and injury report forms that were recorded throughout the season. The Young Guns tournament consisted of 28 competitive matches, comprising 25 group stage matches and 3 final matches. This is equivalent to 740 player-match-hours (forwards: 394.7, 53.3%; backs: 345.3, 46.7%), and 101 match injuries (forwards: 49, 48.5%; backs: 52, 51.5%) that were recorded during this time period. In total, 19 of the injuries sustained during matches were recurring injuries (forwards: 12, 63.2%; backs: 7, 36.8%).

Over the 7-week period (5 round-robin and 2 final stages), there was a total of 10 472 training-hours (forwards: 5 264 training-hours; backs: 5 208 training-hours). Six training injuries (backs: 3, 50.0%; forwards: 3, 50.0%) were recorded throughout the tournament, but none were recurring injuries. There were also no catastrophic or career-ending injuries sustained during the 2022 tournament. One injury had been excluded from the study, because the incident occurred while the player was participating in another activity.

Table 4.5 shows the results for the incidence and proportion of match and training injuries for the different playing groups. The injury incidence for all players was 9.5 injuries/1000 player-hours. The injury incidence for all players during matches was 136.5 injuries/1000 match-hours, whereas during training it was 0.6 injuries/1000 training-hours.

Overall, backs sustained a slightly greater incidence of injuries (9.9 injuries/1000 player-hours) than forwards (9.2 injuries/1000 player-hours). More specifically, the incidence during matches was 124.1 injuries/1000 match-hours for forwards, and 150.6 injuries/1000 match-hours for backs. This illustrates that the injury incidence was greater for backs than forwards (with a difference of 26.5 injuries/1000 match-hours).

However, an equal proportion of injuries was sustained during training by forwards and backs. However, with regard to playing position, the back row sustained a greater incidence of injury in comparison to the front row (91.7 versus 51.1 injuries/1000 match-hours, respectively). Furthermore, the outside backs (left wing, right wing, and fullback) sustained a greater incidence of injury in comparison to the inside backs (inside and outside centres) (117.9 versus 55.7 injuries/1000 match-hours, respectively).

Table 4.5: Incidence (number of injuries per 1000 player-hours) and proportion (%) of injuries sustained by forwards and backs during matches and training.

Playing Position (Player subgroups)	**Incidence of Injury** (injuries/1000 player-hours)	**Proportion of Injury** (%, 95% CI)
	Match Injuries	
All players (n = 101)	136.5	94.4 (88.8 - 98.4)
Forwards (n = 49)	124.1	48.5 (40.4 - 60.2)
Front row (n = 16)	51.1	15.8 (9.5 - 24.2)
Second row (n = 11)	61.1	10.9 (4.5 - 17.8)
Back row (n = 22)	91.7	21.8 (14.9 - 30.5)
Backs (n = 52)	150.6	51.5 (39.8 - 59.6)
Halves (n = 17)	70.8	16.8 (9.9 - 27.9)
Inside backs (n = 13)	55.7	12.9 (5.5 - 18.2)
Outside backs (n = 22)	117.9	21.8 (13.5 - 31.1)
	Training Injuries	
All players (n = 6)	0.6	5.6 (1.6 - 11.2)
Forwards (n = 3)	0.6	50.0 (-)
Backs (n = 3)	0.6	50.0 (-)

Note: 95% CI refers to 95% confidence interval.
(-) indicates missing data for the confidence interval.

4.4 Location, Type and Severity of Injury

4.4.1 Location of Injury

Table 4.6 provides an overview of the anatomical location of injury during the 2022 Young Guns tournament. The injuries were divided into the main groups of 1) head and neck, 2) upper limb, 3) trunk and 4) lower limb, with each main group consisting of specific sub-groups. The lower limb was the most commonly injured anatomical group with 36.6% (95% CI: 27.7% to 48.3%) of the 101 overall injuries sustained. The upper limbs followed with 28.7% injuries (95% CI: 20.0% to 37.0%). The head and neck region sustained a total of 27.7% injuries (95%

CI: 18.8% to 37.4%) and the trunk sustained the least with 6.9% injuries (95% CI: 3.0% to 12.3%). The shoulder/clavicle was the most affected anatomical location with 23.8% injuries (95% CI: 14.9% to 30.5%), followed by the head with 18.8% injuries (95% CI: 11.9% to 27.1%), and the ankle with 11.9% injuries (95% CI: 5.0% to 18.8%). The areas least affected were the neck/cervical spine with 8.9% (95% CI: 3.6% to 15.7%), the anterior thigh with 6.9% (95% CI: 2.6% to 10.9%) and the hip/groin with 4.0% (95% CI: 1.0% to 7.9%). The shoulder/clavicle (forwards: 26.5%; backs: 21.2%) and head (forwards: 18.4%; backs: 19.2%) were common sites of injury amongst both forwards and backs. The forwards also sustained more injuries to the ankle (16.3%), whereas anterior thigh injuries were more prevalent amongst backline players (11.5%).

Table 4.6: Proportion of match injuries sustained according to anatomical location and the playing position.

Injury Location		**All Players**	**Forwards**	**Backs**
Main group	**Sub-group**		**Proportion of injury (%, 95% CI)**	
Head/neck	All injuries	27.7 (18.8 - 37	28.6 (18.4 - 44.3)	26.9 (16.1 - 40.4)
	Head / face	18.8 (11.9 - 27.1)	18.4 (7.4 - 27.9)	19.2 (10.4 - 32.7)
	Neck / cervical spine	8.9 (3.6 - 15.7)	10.2 (2.7 - 20.4)	7.7 (1.9 - 17.7)
Upper limb	All injuries	28.7 (20.0 - 37.0)	32.7 (20.4 - 42.9)	25.0 (11.1 - 37.0)
	Shoulder / clavicle	23.8 (14.9 - 30.5)	26.5 (13.5 - 40.2)	21.2 (8.4 - 33.9)
	Upper arm	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)
	Forearm	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)
	Wrist	2.0 (0.0 - 5.4)	2.0 (0.0 - 7.5)	1.9 (0.0 - 5.8)
	Hand / fingers	3.0 (0.0 - 5.9)	4.1 (0.0 - 12.2)	1.9 (0.0 - 7.7)
Trunk	All injuries	6.9 (3.0 - 12.3)	6.1 (0.6 - 17.1)	7.7 (0.8 - 18.5)
	Upper back / sternum / rib	3.0 (0.0 - 6.7)	4.1 (0.0 - 9.6)	1.9 (0.0 - 5.0)
	Abdomen	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)
	Lower back	4.0 (1.0 - 7.7)	2.0 (0.0 - 7.5)	5.8 (0.0 - 12.7)

	Pelvis / sacrum	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)
Lower limb	All injuries	36.6 (27.7 - 48.3)	32.7 (21.7 - 45.7)	40.4 (24.9 - 58.1)
	Hip / groin	4.0 (1.0 - 7.9)	0.0 (0.0 - 0.0)	7.7 (1.9 - 16.6)
	Thigh (anterior)	6.9 (2.6 - 10.9)	2.0 (0.0 - 6.1)	11.5 (3.8 - 22.3)
	Thigh (posterior)	5.0 (1.0 - 7.9)	4.1 (0.0 - 11.6)	5.8 (0.0 - 11.5)
	Knee	5.9 (2.0 - 11.3)	8.2 (2.0 - 16.3)	3.8 (0.0 - 13.9)
	Lower leg / Achilles	3.0 (0.0 - 5.9)	2.0 (0.0 - 7.5)	3.8 (0.0 - 8.1)
	Ankle	11.9 (5.0 - 18.8)	16.3 (6.8 - 28.6)	7.7 (0.8 - 14.6)
	Foot / toe	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)

Note: 95% CI refers to 95% confidence interval.

Figure 4.2 illustrates the side of the body where injury was sustained, which was recorded as left (37.8 injuries/1000 match-hours) or right (52.7 injuries/1000 match-hours) or bilateral (45.9 injuries/1000 match-hours). There were no statistically significant difference in the anatomical side affected between forwards and backs (U = 1132.5; p = 0.306).

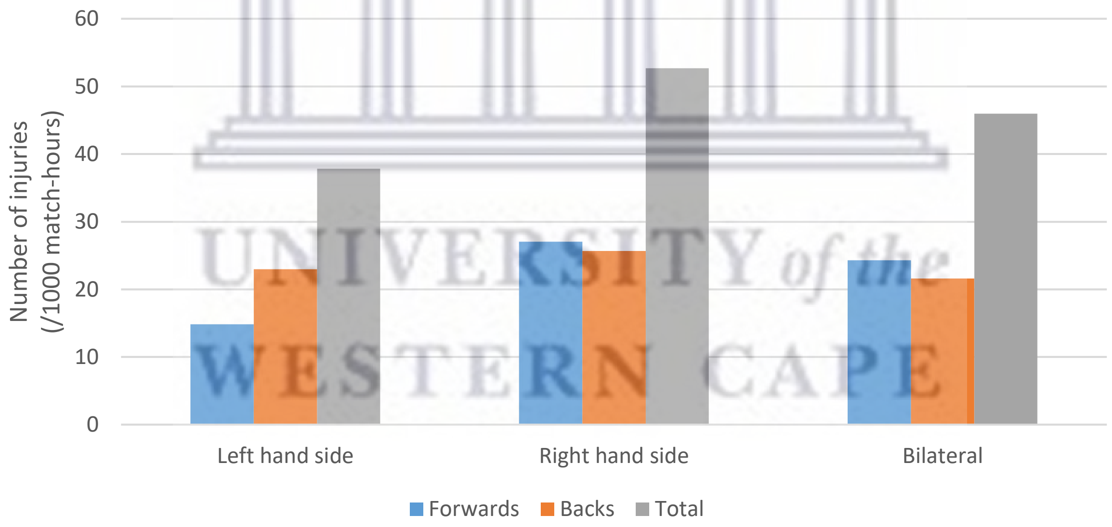

Figure 4.2: Incidence (number of injuries per 1000 match-hours) of injury for forwards and backs according to the anatomical side affected.

4.4.2 Type of Injury

Table 4.7 shows an overview of the types of injuries that were sustained during the Young Guns tournament. The main types of injuries were bones, central and peripheral nervous system, joint/ligamentous, muscular/tendinous and skin. The joints (41.6%, 95% CI: 29.9% to 49.9%) and muscles/tendons (28.7%, 95% CI: 20.8% to 38.0%) of the players were the most commonly affected structures. The structures that were least affected were the bones (5.0%, 95% CI: 1.0% to 10.3%) and skin (1.0%, 95% CI: 0.0% to 3.0%). The two most prominent injury types sustained were ligament injury and concussion. Sprain/ligament injuries were the most common injury type, contributing 35.6% (95% CI: 25.3% to 45.9%) to all injuries, while 16.8% (95% CI: 9.5% to 24.6%) of injuries were concussions. Haematoma/bruise/contusion injuries occurred in 14.9% (95% CI: 7.9% to 21.8%) of cases, strains in 9.9% (95% CI: 5.0% to 16.2%), and dislocations in 4.0% (95% CI: 1.0% to 7.9%). Sprains, concussion and strain injuries were the most common types of injuries sustained by forwards, occurring in 49.0%, 16.3%, and 10.2% of events, respectively. Similarly, backs sustained more contusions, sprains and concussions during matches (23.1%, 23.1% and 17.3%, respectively). There were no statistically significant differences between the types of injuries sustained amongst forwards and backs ($U = 1110.5$; $p = 0.253$).

Table 4.7: Proportion of match injuries sustained according to injury type and the playing position.

Injury Type		All Players	Forwards	Backs
Main group	**Sub-group**	**Proportion of injury (%, 95% CI)**		
Bones	All injuries	5.0 (1.0 - 10.3)	4.1 (0.0 - 13.7)	5.8 (0.0 - 10.8)
	Fractures	5.0 (1.0 - 9.3)	4.1 (0.0 - 8.2)	5.8 (0.8 - 13.5)
	Other bone injuries	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)
Central / Peripheral Nervous system	All injuries	18.8 (9.5 - 27.1)	16.3 (6.8 - 22.4)	21.2 (10.4 - 30.8)
	Concussion	16.8 (9.5 - 24.6)	16.3 (4.7 - 24.5)	17.3 (8.4 - 29.7)
	Nerve injury	2.0 (0.0 - 5.9)	0.0 (0.0 - 0.0)	3.8 (0.0 - 7.7)
Joint (non-bone) / Ligament	All injuries	41.6 (29.9 - 49.9)	53.1 (37.4 - 68.8)	30.8 (21.9 - 45.4)
	Dislocation / subluxation	4.0 (1.0 - 7.9)	2.0 (0.0 - 6.1)	5.8 (0.0 - 15.4)
	Lesion meniscus / cartilage / disc	2.0 (0.0 - 6.3)	2.0 (0.0 - 7.5)	1.9 (0.0 - 5.8)
	Sprain / ligament	35.6 (25.3 - 45.9)	49.0 (34.7 - 64.7)	23.1 (12.3 - 35.8)
Muscle / tendon	All injuries	28.7 (20.8 - 38.0)	20.4 (6.0 - 34.1)	36.5 (24.6 - 46.2)
	Haematoma / contusion / bruise	14.9 (7.9 - 21.8)	6.1 (0.6 - 13.0)	23.1 (12.3 - 36.5)
	Muscle rupture / tear / strain / cramp	9.9 (5.0 - 16.2)	10.2 (2.0 - 21.8)	9.6 (0.8 - 19.2)
	Tendon rupture / tendinopathy / bursitis	4.0 (0.6 - 7.9)	4.1 (2.0 - 21.8)	3.8 (0.0 - 10.0)
Skin	All injuries	1.0 (0.0 - 3.0)	0.0 (0.0 - 0.0)	1.9 (0.0 - 8.9)
	Abrasion	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)	0.0 (0.0 - 0.0)
	Laceration	1.0 (0.0 - 3.0)	0.0 (0.0 - 0.0)	1.9 (0.0 - 6.9)
Other	Other injuries	5.0 (0.6 - 9.9)	6.1 (2.0 - 17.1)	3.8 (0.0 - 10.8)

Note: 95% CI refers to 95% confidence interval.

4.4.3 Severity of Injury

Table 4.8 illustrates the severity of injury for match and training injuries, and were grouped according to minimal, mild, moderate and severe. Most of the injuries sustained (29.7%, 95% CI: 22.8% to 36.0%), were moderate, followed by 22.8% (95% CI: 15.4% to 31.5%) that were mild. Furthermore, 15.8% of injuries were severe, resulting in the players missing training sessions and matches for 28 or more days. In addition, 17.8% (95% CI: 9.1% to 26.1%) and 8.9% (95% CI: 4.0% to 14.9%) of the remaining injuries were minimal and slight, respectively. In match situations, the forwards were more prone to moderate injuries (34.7%, 95% CI: 24.5% to 51.0%), whereas backs sustained more mild injuries (28.8%, 95% CI: 15.0% to 39.6%).

There was no significant association between the severity of match injuries and the different playing positions ($\chi2(1) = 2.9$; $p = 0.717$).

Table 4.8: Proportion of match injuries sustained according to injury severity and the playing position.

Severity of Injury (Days absent)	**All Players**	**Forwards**	**Backs**
	Proportion of injury (%, 95% CI)		
Slight (0 – 1)	8.9 (4.0 - 14.9)	10.2 (0.6 - 18.4)	7.7 (0.8 - 17.7)
Minimal (2 – 3)	17.8 (9.1 - 26.1)	18.4 (8.2 - 33.4)	17.3 (7.3 - 31.9)
Mild (4 – 7)	22.8 (15.4 - 31.5)	16.3 (6.8 - 30)	28.8 (15.0 - 39.6)
Moderate (8 – 28)	29.7 (22.8 - 36)	34.7 (24.5 - 51)	25.0 (8.4 - 34.6)
Severe (>28)	15.8 (9.5 - 23.8)	16.3 (3.3 - 32.2)	15.4 (5.8 - 28.8)
Not mentioned#	5.0 (1.0 - 9.3)	4.1 (0.0 - 10.2)	5.8 (0.8 - 13.5)

Note: 95% CI refers to 95% confidence interval.
refers to the severity of injury sustained that was not reported.

4.4.3.1 Common Match Injuries Causing Absence from Full Sport Participation

Table 4.9 shows the five most common injuries sustained during matches, accompanied by the five injuries that resulted in the most days that players were absent from participation. The total number of days absent for the five most common injuries was 678 days, which were also the same injuries causing the most days absent from participation, except for thigh fracture, and totalled 845 days.

Overall, the total number of days absent from participation for forwards was 813 days compared to backs with 509 days. A total of 1 464 player-days were lost due to injury throughout the tournament. This is a result of the 101 injuries (forwards: 49 injuries, 813 days; backs: 52 injuries, 509 days) sustained during matches and 6 injuries (forwards: 3 injuries, 14 days; backs: 3 injuries, 128 days) sustained during training. The mean number of days absent from participation equated to 14.5 days, due to the 101 match injuries. A statistically significant association was found between the severity of injury and exposure activity (training or competitive match) ($\chi 2(1) = 11.3$; $p = 0.047$).

Table 4.9: The most prevalent injuries and the injuries causing the most number of days absent from participation.

Most Prevalent Injuries	**Number** (n)	**Percent** (%)	**Absence** (days)
Concussion	17	16.8	175
Shoulder ligament	11	10.9	137
Ankle ligament	10	9.9	138
Anterior thigh contusions	6	5.9	27
Shoulder dislocation	4	4.0	201
Total	48	47.5	678
Other injuries	59	52.5	786

Total of all injuries	107	100	1464
Injuries Causing the Most Number of Days Absent			
Shoulder dislocation	4	4.0	201
Thigh fracture	2	2.0	194
Concussion	17	16.8	175
Ankle ligament	10	9.9	138
Shoulder ligament	11	10.9	137
Total	44	43.6	845
Other injuries	63	56.4	619
Total of all injuries	107	100	1464

Figure 4.3 illustrates the injuries sustained during matches that resulted in the greatest number of days absent from participation. Although only 4.0% of injuries sustained were shoulder dislocation, it resulted in the greatest number of days absent (201 days). This was closely followed by thigh fracture (2.0% of injuries; 194 days absent), concussion (16.8% of injuries; 175 days absent), ankle ligament (9.9% of injuries; 138 days absent) and shoulder ligament (10.9% of injuries; 137 days absent).

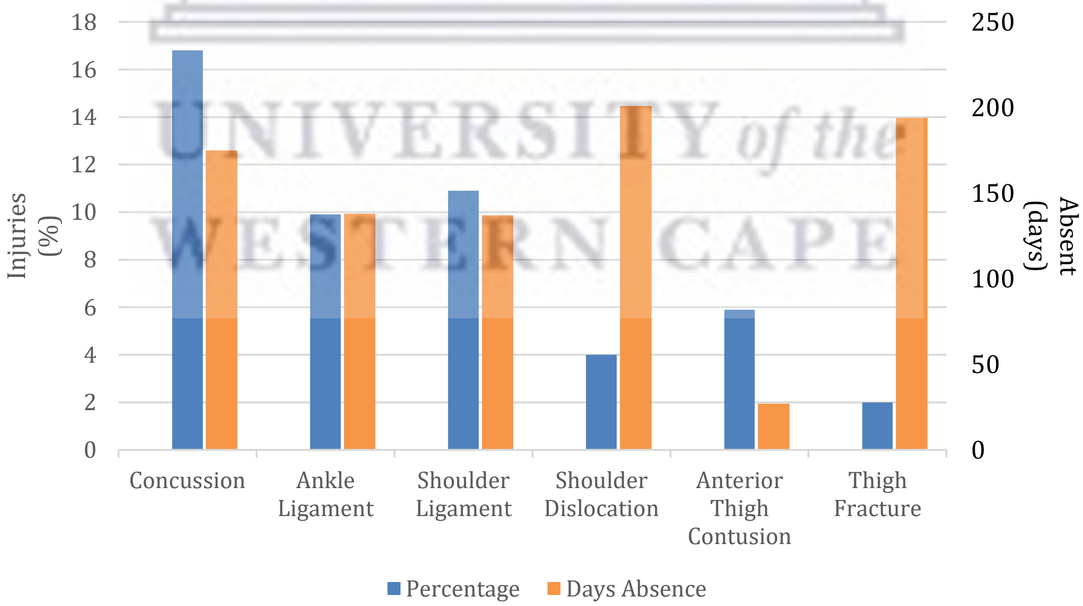

Figure 4.3: The proportion of injury and days absent from participation caused by the most common injuries.

4.4.3.2 New or Recurring Injury

From the 101 match injuries sustained, 19 were recurring injuries, while 82 were new injuries (Figure 4.4). This resulted in an overall incidence for recurrent and new injuries of 25.7 injuries/1000 match-hours (17.8%, 95% CI: 9.8% to 25.5%) and 110.8 injuries/1000 match-hours (82.2%, 95% CI: 74.5% to 90.2%), respectively. The most common type of recurrent injury, across the season, was moderate in nature (8 – 28 days lost). However, there were no statistically significant association between the severity of injury and recurring or new injuries ($\chi2(1) = 4.0$; $p = 0.551$). A statistically significant association was shown between injury type and whether recurring or new injuries ($\chi2(1) = 18.8$; $p = 0.043$). In addition, a statistically significant association was also found between the nature of the injury (overuse or trauma) and whether recurrent or new injuries ($\chi2(1) = 8.7$; $p = 0.003$).

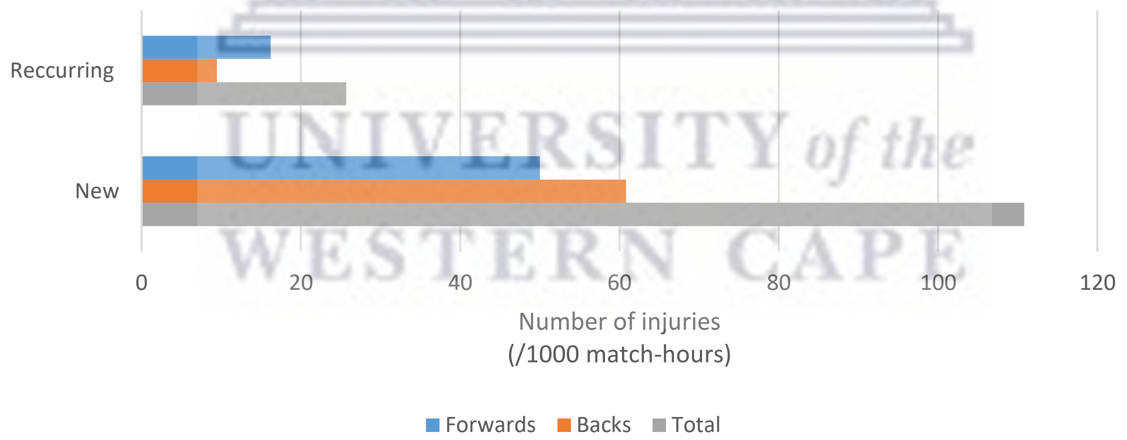

Figure 4.4: Incidence (number of injuries per 1000 match-hours) of new and recurring injuries for forwards and backs.

4.5 Injury Occurrence Based on the Phase of Play

Contact injuries resulting in trauma accounted for 91.1% (95% CI: 86.1% to 96.4%) of injuries and were the most common cause of match injury, with only 8.9% (95% CI: 3.6% to 13.9%) of injuries being the result of overuse of non-contact activities. Physical contact was the main inciting event for all match and training injuries (88.1% and 7.1%, respectively). Overall, 124.3 injuries/1000 match-hours were most commonly caused by trauma and 12.2 injuries/1000 match-hours were sustained by overuse (Figure 4.5).

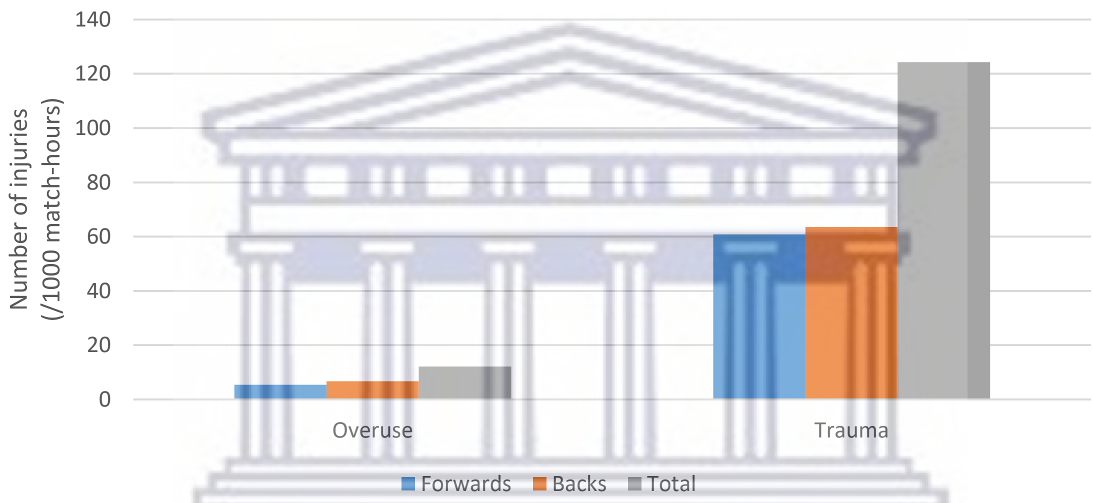

Figure 4.5: Incidence (number of injuries per 1000 match-hours) of overuse and trauma injuries for forwards and backs.

The proportion of match injuries, linked to the specific event at the time of injury, is shown in Table 4.10. The nature of these injuries is distributed as follows: tackling with 28.7% (95% CI: 18.8% to 42.6%), collision with 13.9% (95% CI: 6.9% to 20.2%), being tackled with 10.9% (95% CI: 5.9% to 16.8%) and the scrum with 9.9% (95% CI: 4.0% to 16.2%). Furthermore, not all teams provided specific events that led to injury, resulting in 16.8% (95% CI: 8.9% to 23.6%) of injuries recorded as contact-related, which could have been considered as either tackling, being tackled, maul, ruck, scrum, lineout or collision injuries. A statistically significant association was found between the playing position and the phase of play ($\chi2(1) = 160.2$; $p = 0.021$).

Table 4.10: Proportion of injuries sustained by forwards and backs based on match activity.

Match Activity	**All Players**	**Forwards**	**Backs**
	Proportion of injuries (%, 95% CI)		
Lineout	3.0 (0.0 - 6.3)	6.1 (0.6 - 15.7)	0.0 (0.0 - 0.0)
Maul	2.0 (0.0 - 5.0)	4.1 (0.0 - 10.2)	0.0 (0.0 - 0.0)
Ruck	8.9 (3.6 - 16.7)	12.2 (6.1 - 22.4)	5.8 (0.0 - 13.5)
Scrum	9.9 (4.0 - 16.2)	20.4 (10.8 - 32.0)	0.0 (0.0 - 0.0)
Tackled	10.9 (5.9 - 16.8)	10.2 (2.7 - 19.8)	11.5 (2.7 - 22.3)
Tackling	28.7 (18.8 - 42.6)	22.4 (6.1 - 35.5)	34.6 (21.5 - 48.9)
Collision	13.9 (6.9 - 20.2)	12.2 (4.1 - 22.4)	15.4 (7.7 - 28.5)
Contact-related[#]	16.8 (8.9 - 23.6)	10.2 (0.6 - 18.4)	23.1 (10.4 - 36.5)
Other[$]	5.0 (1.0 - 9.9)	0.0 (0.0 - 0.0)	9.6 (2.7 - 18.5)
Not identified[+]	1.0 (0.0 - 3.0)	2.0 (0.0 - 8.9)	0.0 (0.0 - 0.0)

Note: 95% CI refers to 95% confidence interval.
[#] refers to injuries caused by contact events during a match.
[$] refers to injuries caused by mechanisms that were outside of match activities.
[+] refers to injuries where the specific match activity was not mentioned.

4.6 Injury Occurrence Based on the Playing Position

The total number of match injuries sustained, including the overall match injury incidence, between player groups were very similar (forwards: 49 injuries, 48.5%, 124.1 injuries/1000 match-hours; backs: 52 injuries, 51.5%, 150.6 injuries/1000 match-hours). Despite the backs sustaining a slightly greater number of injuries and reporting a higher injury incidence than the forwards, there was no significant difference in the number or incidence of match injuries between the two positional groups during the season.

Figure 4.6 illustrates that the majority of injuries that were sustained were by players who started the match (97.3 injuries/1000 match-hours), while only 9.5 injuries/1000 match-hours were by substitutes. It is important to note that in 29.7 injuries/1000 match-hours, it was not indicated whether the player started the match or was a substitute.

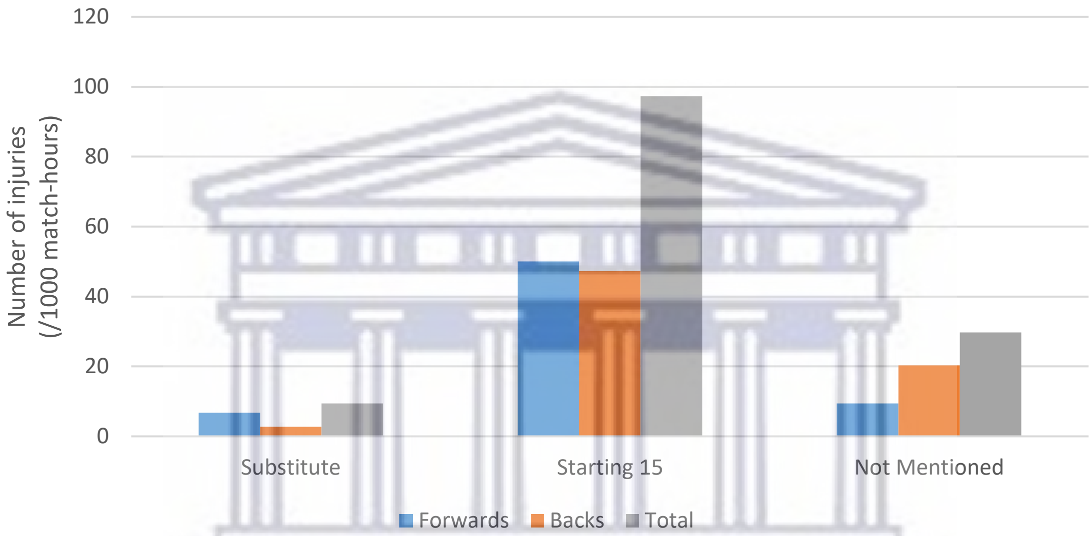

Figure 4.6: Incidence (number of injuries per 1000 match-hours) of injury for forwards and backs according to the players' starting or substitution status.

The rate of injury according to playing position is shown in Figure 4.7. Although there were no significant differences in injury rates between playing positions, the positions that were most prone to injury were the inside centre, flyhalf, tighthead prop, number 8 and fullback. The inside centre (11.9%, 95% CI: 6.5% to 19.8%) and number 8 (11.9%, 95% CI: 4.0% to 18.8%) had the highest injury rates, followed by the fullback, flyhalf, tighthead prop, openside flanker, and number 5 lock with 9.9% (95% CI: 3.6% to 16.8%), 8.9% (95% CI: 3.6% to

15.3%), 7.9% (95% CI: 2.6% to 12.9%), 7.9% (95% CI: 4.0% to 13.7%) and 7.9% (95% CI: 3.0% to 12.3%), respectively. The number 4 lock and loose-head prop both sustained 3.0% (95% CI: 0.0% to 6.3%) of injuries, while the blindside flanker and outside centre both sustained 2.0% (95% CI: 0.0% to 5.4%) of injuries, which were the least number of injuries throughout the tournament.

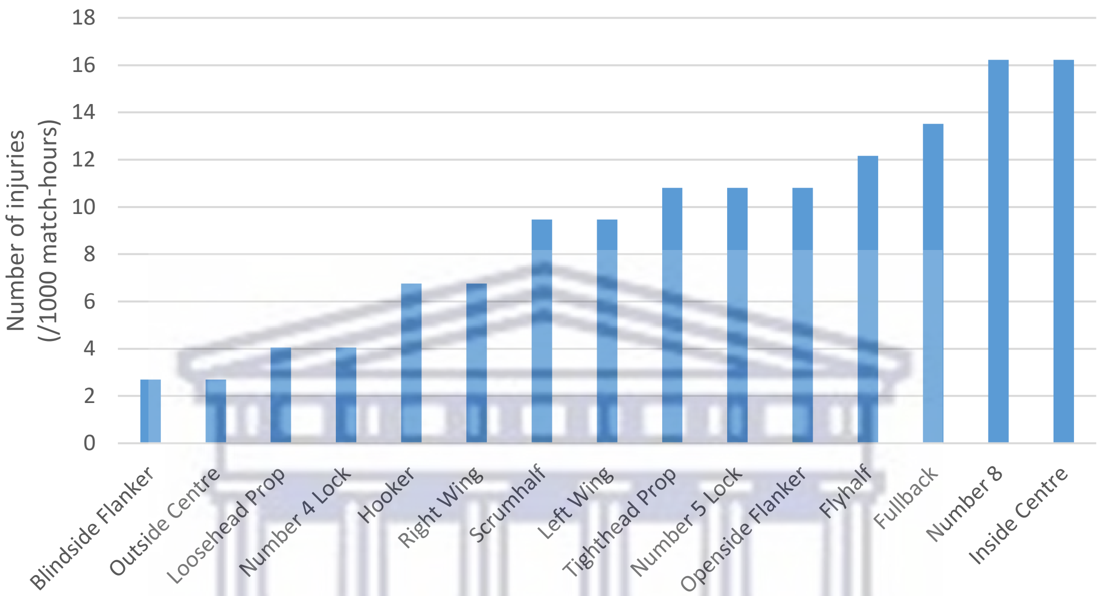

Figure 4.7: Incidence (number of injuries per 1000 match-hours) of injury according to the playing position.

4.7 Injury Occurrence Based on the Playing Quarter of the Game

The majority of injuries sustained during the tournament occurred in the second-half of the match (47.5%, 95% CI: 39.6% to 58.4%), in comparison to 30.7% (95% CI: 21.0% to 38.0%) in the first-half. When reported per quarter of the match, then the number of injuries sustained during the first quarter was the lowest with 8 injuries (7.9%) (forwards: 6; backs: 2) (95% CI: 3.0% to 13.3%), the second quarter was 23 (22.8%) (forwards: 16; backs: 7) (95% CI: 14.9% to 30.7%), the third quarter was the highest with 27 (26.7%) (forwards: 12; backs: 15) (95%

CI: 17.8% to 36.6%) and the fourth quarter was 21 (20.8%) (forwards: 8; backs: 13) (95% CI: 11.5% to 28.7%) (Table 4.11). In addition, a certain number of injuries were not specified per quarter of the match i.e., 22 (21.8%) (forwards: 7; backs: 15) (95% CI: 13.5% to 30.5%).

Statistically significant differences were present between forwards and backs based on the particular half of the match (U = 526.0; p = 0.011), and between the second and fourth quarters of the match (U = 165.5; p = 0.038).

Table 4.11: Proportion of injuries sustained by forwards and backs according to the playing period in the match.

Playing Period in Match	**All Players**	**Forwards**	**Backs**
		Proportion of injury (%, 95% CI)	
First half	30.7 (21.0 - 38.0)	44.9 (7.1 - 31.2)	17.3 (6.7 - 28.5)
First quarter: 0 – 20 min	7.9 (3.0 - 13.3)	12.2 (1.9 - 22.4)	3.8 (0.0 - 9.6)
Second quarter: 21 – 40+ min	22.8 (14.9 - 30.7)	32.7 (20.4 - 42.9)	13.5 (5.8 - 21.6)
Second half	47.5 (39.6 - 58.4)**	40.8 (7.9 - 24.5)	53.8 (41.1 - 73.2)
Third quarter: 41 – 60 min	26.7 (17.8 - 36.6)	24.5 (11.5 - 34.1)	28.8 (21.1 - 46.6)
Fourth quarter: 61 – 80+ min	20.8 (11.5 - 28.7)*	16.3 (6.1 - 27.9)	25.0 (10.4 - 37.0)
Not mentioned#	21.8 (13.5 - 30.5)	14.3 (2.7 - 26.7)	28.8 (18.8 - 40.8)

Note: * indicates significant difference between forwards and backs $p < 0.05$.
** indicates significant difference between forwards and backs $p < 0.01$.
95% CI refers to 95% confidence interval.
# indicates that the period of the match in which injury was sustained, but was not reported.

4.8 Injury Occurrence Based on Foul Play

The results indicated that 20 match injuries (19.8%, CI 95%: 12.8 to 26.4) or 27.0 injuries/1000 match-hours were sustained as a result of foul play (Figure 4.8). Amongst the forwards, the number 8 position (4 injuries), was the most susceptible position to injury, due to foul play, whereas amongst the backs, it was the left wing and inside centre (both 3 injuries). Physical contact activities, such as the tackle and being tackled, were deemed illegal and resulted in 10 (9.9%) injuries during the tournament. In ten (9.9%) of the injuries, due to foul play, players were not making use of any form of protective equipment. Furthermore, nine (8.9%) injuries (5 leading to concussion) that were sustained because of foul play were considered dangerous, because they affected the head and neck/cervical spine region. Non-specified play refers to injuries sustained during matches that were not specified as being either due to foul or dangerous play, which totalled 31.1 injuries/1000 match-hours.

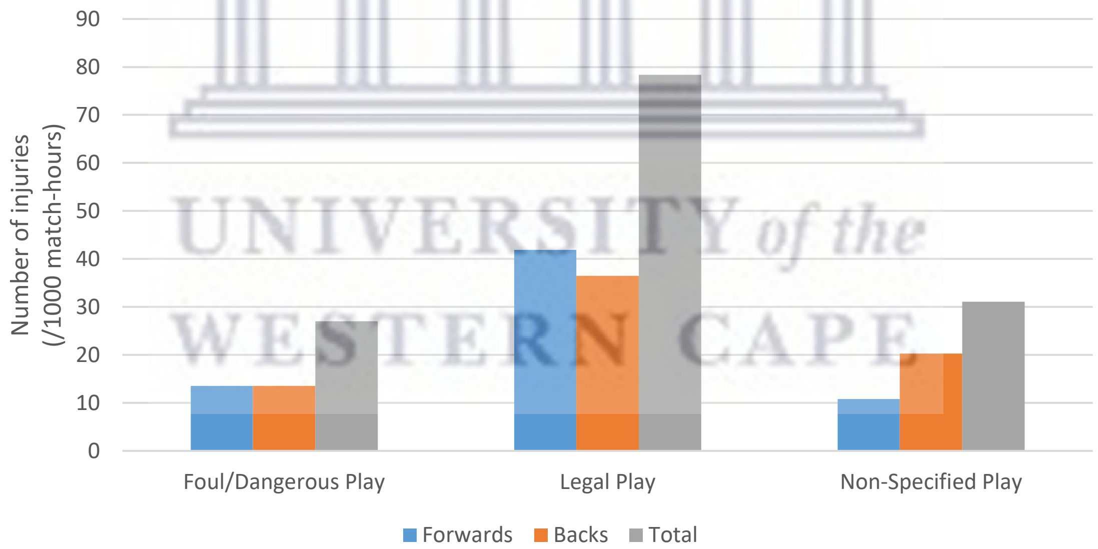

Figure 4.8: Incidence (number of injuries per 1000 match-hours) of injuries for forwards and backs due to foul or dangerous play.

4.9 Injury Occurrence Based on the Field of Play

The rugby playing field is divided into two halves, and each with two equal halves on either side of the 50 m line, namely the offensive and defensive halves. More injuries were sustained while players were in the offensive half of the field. More precisely, 41.6% (95% CI: 32.3% to 53.9%) of injuries were sustained while in the offensive half, while 33.7% (95% CI: 23.8% to 41.4%) were sustained while playing in the defensive half. Furthermore, based on playing zones, 23.8% (95% CI: 15.4% to 33.5%) of injuries were between the opposition-22 and halfway line, 17.8% (95% CI: 11.5% to 27.1%) was in the player's own-22 m area, 17.8% (95% CI: 9.9% to 25.7%) were in the opposition-22 m area, 15.8% (95% CI: 8.5% to 23.8%) were between the player's own-22 and halfway line, and 2.0% (95% CI: 0.0% to 5.4%) were in the in-goal area, while the location of 22.8% (95% CI: 13.9% to 33.7%) of injuries was not specified (Table 4.12). There was no association between the activity causing injury and the area of the field in which injury occurred ($\chi2(1) = 107.3$; $p = 0.217$).

Table 4.12: Proportion of injuries sustained by forwards and backs based on the area of the field in which injury was sustained.

Area of Field	All Players	Forwards	Backs
	Proportion of injury (%, 95% CI)		
Own-22	17.8 (11.5 - 27.1)	22.4 (8.8 - 41.7)	13.5 (4.6 - 25.0)
Opposition-22	17.8 (9.9 - 25.7)	12.2 (2.7 - 23.9)	23.1 (12.3 - 32.7)
Between own-22 and halfway line	15.8 (8.9 - 24.2)	16.3 (6.1 - 30)	15.4 (3.4 - 28.8)
Between opposition-22 and halfway line	23.8 (15.8 - 34.5)	32.7 (16.3 - 46.3)	15.4 (4.6 - 26.2)
In-goal area	2.0 (0.0 - 5.0)	2.0 (0.0 - 7.5)	1.9 (0.0 - 5.8)
Not specified#	22.8 (14.9 - 33.1)	14.3 (6.1 - 26.5)	30.8 (12.3 - 43.5)

Note: 95% CI refers to 95% confidence interval.
refers to the area of the field, where injury occurred, that was not specified.

4.10 Injury Occurrence Based on Protective Equipment

During the 2022 Young Guns tournament, the majority of the players who sustained injuries made use of mouth-guards as protective equipment. However, the total number of players who wore protective equipment across the entire tournament was unclear. Out of the 101 match injuries, in 43.6% (59.5 injuries/1000 match-hours) of these events, the players were using either a mouth-guard, shoulder padding or headgear as protective equipment. This suggests that many players did not use protective equipment when injured (34.7% and 47.3 injuries/1000 match-hours) (Figure 4.9). Concussion injuries are extremely concerning and highly prevalent central nervous system injuries in rugby. Of the 17 concussions sustained during the tournament, players were wearing either mouth-guards or headgear in only 8 of these cases. This meant that in three concussion events, no protective gear was worn, and in the remaining six concussions, it was not clear whether or not the players were wearing any protective equipment. When considering severe injuries, only four players were wearing some form of protective equipment at the time of injury (compared to seven events in which no protective equipment was worn). A greater number of players sustained injury, while performing a tackle or being involved in a collision, with no protective equipment worn. Note: In the figure, not specified indicates that the type of protective equipment was not specified, when injury was sustained. There was a statistically significant association between the severity of injury and the use of protective gear ($\chi2(1) = 43.8$; $p = 0.002$).

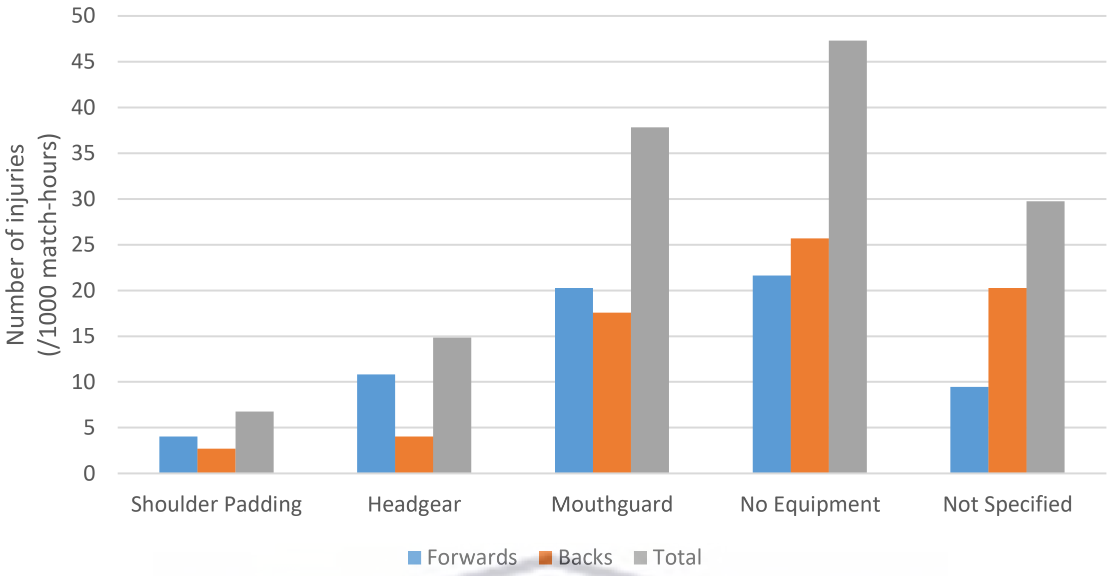

Figure 4.9: Incidence (number of injuries per 1000 match-hours) of injuries for forwards and backs based on protective equipment.

4.11 Predicting the Risk of Injury Based on the Playing Position

Table 4.13 represents the results of the regression analysis that was used to predict the risk of injury based on playing position. Both forwards and backs were at higher risk of injury to the anterior thigh (b = -2.5, Wald $\chi2(1)$ = 4.0, p = 0.045, OR = 0.1, 95% CI: 0.0 to 1.0), while playing between the opposition-22 and the halfway line of the field (b = 1.3, Wald $\chi2(1)$ = 4.5, p = 0.035, OR = 3.6, 95% CI: 1.1 to 11.5), during either the first quarter (0 to 20 minute) or second quarter (21 to 40+ minute) (b = 1.9, Wald $\chi2(1)$ = 4.0, p = 0.047, OR = 6.4, 95% CI: 1.0 to 40.3 and b = 1.6, Wald $\chi2(1)$ = 6.1, p = 0.014, OR = 4.9, 95% CI: 1.4 to 17.3, respectively). Players were also at greater risk of sustaining injury to the head, while wearing protective equipment (b = 1.7, Wald $\chi2(1)$ = 4.3, p = 0.037, OR = 5.3, 95% CI:1.1 to 25.8). Also, the number 8 position was at increased risk of sustaining injury, during the second quarter (21 to 40+ minutes) of the match (b = 3.2, Wald $\chi2(1)$ = 4.2, p = 0.041, OR = 24.0, 95% CI:

1.1 to 505.2), and the inside centres were at increased risk of injury during legal play (b = 2.7, Wald $\chi2(1) = 4.5$, $p = 0.35$, OR = 15.0, 95% CI: 1.2 to 185.2). No other physical characteristics or injury characteristics displayed statistical significance ($p < 0.05$).

Table 4.13: Predicting the risk of injury based on playing position.

Parameter Estimates									
								95% CI for Exp(B)	
		B	Std. Error	Wald	df	Sig.	Exp(B)	Lower Bound	Upper Bound
All players	Between opposition-22 and halfway line	1.269	.601	4.456	1	.035	3.556	1.095	11.546
All players	Quarter 1	1.861	.936	3.952	1	.047	6.429	1.026	40.261
All players	Quarter 2	1.589	.644	6.085	1	.014	4.898	1.386	17.310
All players	Anterior thigh	-2.485	1.242	4.005	1	.045	.083	.007	.950
All players	Headgear	1.674	.804	4.339	1	.037	5.333	1.104	25.767
Number 8	Quarter 2	3.178	1.555	4.179	1	.041	24.000	1.140	505.194
Inside centre	Legal play	2.708	1.282	4.460	1	.035	15.000	1.215	185.198

CHAPTER FIVE: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The Young Guns tournament, played at university-level, provides under-20 players a platform to showcase their talent and skill (Potgieter *et al.*, 2014). The platform identifies players who have the potential to become professionals in the sport (Dimundo, Cole, Blagrove, McAuley, Till *et al.,* 2021). Due to the contact nature of rugby, the sport is known to have a high incidence of injury compared to other sports (Fuller, Taylor, Kemp, & Raftery, 2017; Roberts *et al.*, 2017; Yeomans *et al.*, 2018; Fuller *et al.*, 2020). Rugby comprises of intense periods of activity including tackling and sprinting, as players are exposed to approximately an average of 29-55 physical collisions per game (King, Clark, Hume, & Hind, 2022).

Comparing injury incidence often proves to be challenging, as previous literature on Rugby Union uses different frameworks and definitions or neglects to capture specific information, while completing injury surveillance across different levels of competition (MacQueen & Dexter, 2010). The use of recommended frameworks in the present study was to ensure consistency in data collection, injury definitions, and reporting on findings (Bahr *et al.*, 2020b). Despite the importance of utilizing present injury data designs and templates in an attempt to reduce the incidence of injuries in rugby, there is currently no accurate and consistent research model or design to investigate the epidemiology of injuries within university rugby, especially at the under-20 level (Barrett, 2015; Brown *et al.*, 2012; Falkenmire *et al.*, 2020; Finch, 2012; Hillhouse, 2013; Lombard *et al.*, 2015).

The objectives of the present study were, firstly, to determine the incidence, type, severity, and location of injury among the Young Guns players, secondly, to determine the risk factors of injury based on playing position and, thirdly, to predict the risk of injury based on playing position. This section, therefore, discusses the incidence of injury among Young Guns rugby players, the relationship between risk factors and occurrence of injury, as well as the factors predicting the risk of injury based on playing position.

5.2 Anthropometric Characteristics of the Players

The Young Guns rugby players had significant differences in height and weight, especially between the forwards and backs that was supported by previous research (Fuller *et al.*, 2020; Potgieter *et al*., 2014). Forwards were significantly heavier than backs. Previous studies emphasize the importance of anthropometric characteristics on team success as teams with stronger players, heavier forwards and faster backs achieved success in competitions (Vaz, Kraak, Batista, Honorio, & Miguel Fernandes, 2021).

When compared to the normative data for stature and body mass of the under-21 South African national rugby players, both forwards and backs in this study were within the norms and compared favourably to the national players (BokSmart Fitness Testing Normative Data, 2019). The alignment of anthropometric characteristics for playing positions allows for accurate selection of players to perform key roles and cope with the position-specific demands of the game (Dimundo *et al*., 2021).

The aerobic fitness test results of the Young Guns players showed that slightly less than a third (29.7%) of forwards and nearly a half (48.7%) of the backs were below the Bronco reference points. Alternatively, neither forwards nor backs performed well-enough to be below or within range of the reference points for the Yo-Yo test. In Rugby, a significant association was found between the Yo-Yo test, as an indicator of maximal aerobic capacity ($\dot{V}O_2max$), and player movement using the global positioning system (GPS) during a match (Pedro, Rodrigo, & Jair, 2020). This is important as a greater $\dot{V}O_2max$ increased the number of high-intensity efforts and the distance covered, while playing (Pedro, Rodrigo, & Jair, 2020). The difference in $\dot{V}O_2max$ between playing positions is due to the game's physical demands, which requires backs to cover more distance at higher intensity compared to forwards (Pedro, Rodrigo, & Jair, 2020).

Previous studies showed that significant relationships existed between anthropometric characteristics, physical fitness, and injuries per playing position, indicating that players with greater fat mass and lower maximal aerobic capacity were at higher risk of injury (Ball, Halaki, & Orr, 2020; Mirsafaei Rizi, Yeung, Stewart, & Yeung, 2017). A greater body and, specifically, fat mass often indicated players with lower aerobic fitness levels. Therefore, the association between the anthropometric characteristics, aerobic fitness and susceptibility to injury means that players with greater fat mass and lower aerobic fitness levels were unable to withstand the demands of the match and, therefore, more injury-prone (Ball *et al*., 2020).

Consequently, research in this area helped to refine and improve training techniques and programmes that resulted in bigger, faster, and more powerful players, especially at the elite level (Lombard *et al*., 2015). Through sport-specific training that targeted endurance, speed, agility, power and flexibility, coaches produced versatile and conditioned rugby players, who adapted well to the demands of a high-intensity contact sport (Lombard *et al*., 2015; Potgieter *et al*., 2014). Thus, many studies reported an association between the players' physical characteristics and match statistics, reinforcing the importance of developing the physical characteristics of players to improve match performance (Ball *et al*., 2020; Lombard *et al*., 2015).

5.3 Injury Incidence During Training and Matches

The incidence of match injuries (136.5 injuries/1000 match-hours) in this study was much higher than that at Namibian amateur or club level (74.4 injuries/1000 match-hours) (Morkel, 2016), Australian amateur club level (52.3 injuries/1000 match-hours) (Swain *et al*., 2016), and English community-level club rugby (16.9 injuries/1000 match-hours) (Roberts *et al*., 2013). The Young Guns players also had a greater injury incidence than the Youth Rugby Injury Surveillance Project (YRISP) in England for the Under-18 age groups (30.1 injuries/1000 match-hours) (Barden, Hancock, Stokes, Roberts, McKay *et al*., 2021), as well as the 2019 South African Rugby Injury and Illness Surveillance and Prevention Project (SARIISPP) report on youth weeks for time-loss injuries (18.0 injuries/1000 match-hours) and medical attention injuries (45.0 injuries/1000 match-hours) (Paul, Readhead, Viljoen, & Lambert, 2020). At professional level, the incidence rate was 79.4 injuries/1000 match-hours for the 2019 Rugby World Cup (Fuller *et al*., 2020), while for the 2020/2021 Carling Currie Cup competition it was 91.0 injuries/1000 match-hours (Starling *et al*., 2021). The most recent study on Varsity Cup rugby reported an incidence rate of 89.0 injuries/1000 match-hours (Hillhouse, 2013), but, the Varsity Cup Koshuis competition at Stellenbosch University had a significantly lower rate of 17.5 injuries/1000 match-hours across three seasons (Barrett, 2015). The incidence of injury at university-level differed from other levels, due to the level of play and the country of origin, amongst other factors (Ogaki *et al.*, 2020). Furthermore, the Young Guns players might not be adequately prepared for the demands of Varsity Cup rugby, e.g., higher intensity of play, increased amount of contact events, and the improved physical and skill attributes required at that level may result in a higher injury incidence (Hillhouse, 2013; Morkel, 2016). The lower incidence rates in other competitions could be attributed to the development in injury prevention measures (Barrett, 2015). A number of interventions were implemented, mainly at a professional level, to protect players from injury (Barden *et al*., 2020; Falkenmire *et al*., 2020).

The incidence of training injuries for the Young Guns players (0.6 injuries/1000 training-hours) was lower to that of the 2011 Varsity Cup competition (1.6 injuries/1000 training-hours) (Hillhouse, 2013) and the 2020/2021 season of the Carling Currie Cup competition (2.6 injuries/1000 training-hours) (Starling *et al*., 2021). The training injuries usually occurred while players participated in full- and semi-contact skills drills (Fuller *et al*., 2017; Starling *et al*., 2021). The literature reported that training injuries were less than match injuries (Morkel, 2016). Players were at greater risk during matches, due to more frequent high-intensity running and impact with full-contact play (Hillhouse, 2013; Ogaki *et al*., 2020). This confirmed that the training injury incidence at amateur or recreational level was similar to that at professional level (Morkel, 2016).

5.4 Location, Type and Severity of Injury

5.4.1 Location of Injury

In the present study, the majority of the injuries were to the lower limb (36.6%), which was consistent with previous studies that showed higher injury rates to the lower limb at youth, amateur and professional levels (Morkel, 2016; Paul *et al.*, 2020; Whitehouse *et al.*, 2016). Furthermore, the injury characteristics showed that the most common anatomical locations were the shoulder/clavicle (23.8%), head (18.8%), ankle (11.9%) and neck/cervical spine (8.9%). The results based on the location of injury varied across the different levels of play in rugby (Hillhouse, 2013; Morkel, 2016; Ogaki *et al*., 2020; Paul *et al.*, 2020; Whitehouse *et al*., 2016). The lower body was the most common location of injury at amateur-club level (ankle ligament sprains 17.3%, hamstring injuries 16.7% and knee injuries 15.4%) (Morkel, 2016). At elite level, the three most common injured regions were the posterior thigh (10.9%), knee (15.6%) and head/face (21.9%) at the 2019 RWC, and the ankle (12.0%), shoulder (18.0%) and head (44.0%) at the 2019 Currie Cup rugby tournament in SA (Fuller, Taylor, Douglas, & Raftery, 2019; Starling *et al*., 2020). In Japanese collegiate rugby players, the shoulder (14.4%), thigh (15.1%) and ankle (17.5%) were the most commonly injured anatomical sites (Ogaki *et al*., 2020).

In the present study, more injuries were sustained to the right side of the players' bodies (51.3 injuries/1000 match-hours), rather than the left side (36.8 injuries/1000 match-hours) or bilateral injury (44.7 injuries/1000 match-hours). During the 2011 Varsity Cup competition, injuries occurred predominantly in the lower limb (50.0 injuries/1000 match-hours) affecting the ankle and foot mainly, followed by head/neck (24.5 injuries/1000 match-hours), and upper limb (24.5 injuries/1000 match-hours) (Hillhouse, 2013). Forwards were at increased risk for shoulder injury (Hillhouse, 2013; Leahy, Kenny, Campbell, Warrington, Cahalan *et al*., 2022; Ogaki *et al*., 2020), while backs were at increased risk for hamstring injury (Hillhouse, 2013; Ogaki *et al*., 2020).

5.4.2 Type of Injury

In the current study, the main types of injuries were sprain/ligament injury (35.6%) and concussion (16.8%) followed by haematoma/bruise/contusion injuries (14.9%), strains (9.9%) and dislocations (4.0%). Most of these injuries were soft tissue injuries. Alternatively, forwards in the Varsity Cup sustained more sprains (49.0%), while backs experienced more contusions and sprains (23.1% for both), similar to the 2011 competition, where strains and sprains occurred in 9.1% and 8.6% of forwards and 7.4% and 5.7% of backs, respectively

(Hillhouse, 2013). In the present study, 16.8% were concussions compared to 9.1% sustained in the 2011 Varsity Cup tournament (Hillhouse, 2013).

The five most common types of injury in the present study were concussion, shoulder ligament injury, ankle sprain, anterior thigh contusion and shoulder dislocation. It is well-documented that ligament injury was very prevalent across all levels of Rugby Union (Brown, Starling, Stokes, Viviers, Jordaan *et al*., 2019; Cruz-Ferreira *et al*., 2018; Fuller *et al*., 2020; Kaux *et al*., 2015; Murias-lozano *et al*., 2022; Ogaki *et al*., 2020; Sabesan, Steffes, Lombardo, Petersen-Fitts, & Jildeh, 2016; Starling *et al*., 2021). In amateur players aged between 18 and 23 years, the most common injuries were sprains/strains (25.8%), fractures (16.6%) and lacerations (16.4%) (Sabesan *et al*., 2016). Similarly, at professional level in the 2019 RWC, 21.7% and 20.3% of injuries were ligament sprains and muscle strains, respectively (Fuller *et al*., 2020). During the 2021 Currie Cup, contusions/bruises comprised 21.0% of all injuries (Starling *et al*., 2021). This is supported in a review by Kaux *et al*. (2015), who stated that 55.0% of injuries affecting professional players were closed soft tissue injuries. Japanese collegiate rugby players sustained mostly ankle sprains (17.7%), hamstring strains (10.1%) and knee sprains (8.0%) (Ogaki *et al*., 2020), while strains (18.9%), sprains (18.3%) and contusions (10.9%) were sustained by players in Varsity Cup rugby (Hillhouse, 2013).

5.4.3 Severity of Injury

The severity of an injury is defined as the amount of days absent from the day of injury until return to full participation (Bahr *et al*., 2020; Fuller *et al*., 2007). The medical team at each institution, consisting of a medical doctor, physiotherapist and/or biokineticist, diagnosed or determined the severity of the injury, according to the consensus statement on injury definitions and data collection procedures (Fuller *et al*., 2007; Starling *et al*., 2021). In previous studies, injuries sustained were classified as mild, moderate or severe, and the same classification system was followed in the present study as well (Cruz-Ferreira *et al*., 2018; Morkel, 2016; Murias-lozano *et al*., 2022).

In the present study, the majority of injuries (29.7%) were reported as moderate severity, resulting in absence from matches and training between 8 and 28 days compared to moderate injuries reported at 14.8% in South African Super Rugby (Whitehouse *et al*., 2016), 28.1% in Varsity Cup Koshuis competition at Stellenbosch University (Barrett, 2015) and 25.0% in the Currie Cup 2020/21 (Starling *et al*., 2021). In the present study, there was no statistically significant difference in the severity of match injury between forwards and backs, which is supported by the literature (Cruz-Ferreira *et al*., 2018; Fuller *et al*., 2020; Whitehouse *et al*., 2016). There was, however, a statistically significant association between the severity of injury in matches and training (Whitehouse *et al*., 2016). The greater severity for match injuries was due to the number of unpredictable high-speed contact events that occurred, e.g., tackles and rucks (West, Starling, Kemp, Williams, Cross *et al*., 2021). It may also be because of contact events when facing bigger, stronger and faster opposition during matches (West, Williams, Kemp, Cross, McKay *et al*., 2020). The low incidence and severity of injury during training was likely due to the predictable nature of training session drills, and where player exposure to high-risk situations was less (Leahy, Kenny, Campbell, Warrington, Cahalan *et al*., 2021).

In the present study, concussions were the most common injury, but shoulder dislocations resulted in the greatest time loss overall. The average number of days absent from participation for match injuries was 14.5 days, which was approximately half of that shown in previous studies, e.g., 35.6 days (Murias-lozano *et al*., 2022) and 37.5 days (Whitehouse *et al*., 2016). The ability to access medical and rehabilitative services was not consistent across all competitions, which may have affected the difference in return-to-play times (Leahy *et al*., 2021). West *et al.* (2021) explained that a delayed and prolonged return-to-play occurred, when medical practitioners used a more conservative return-to-play strategy.

Overall, injuries of moderate severity were more prevalent amongst forwards, while backs sustained more mild injuries. In the literature, backs were reported to sustain more severe injuries (31.8 days) compared to forwards (Cruz-Ferreira *et al*., 2018). In the present study, injuries sustained during matches, that were classified as severe, were shoulder dislocation, ankle sprain, clavicle fracture and femoral fracture. Approximately 45.5% of injured players were excluded from participating in matches and training for more than a week, compared to 42.0% for the Varsity Cup Koshuis competition and 87.7% for Namibian club rugby (Barrett, 2015; Morkel, 2016). However, there were no career-ending or catastrophic injuries recorded during the Young Guns tournament (Cruz-Ferreira *et al*., 2018; Morkel, 2016).

5.4.4 New and Recurring Injury

In the present study, a total of 88 injuries were new injuries and 19 were recurring injuries. In the existing literature, even at university level, the number of new injuries was more than recurrent injuries (Archbold *et al*., 2018; Barrett, 2015; Hillhouse, 2013). In contrast, players younger than 21 years sustained more recurrent than new injuries (Morkel, 2016). Most notably, the recurrent injuries were more severe than new injuries (MacQueen & Dexter, 2010). Recurrent head injuries, specifically concussions, in adolescent rugby players were found to occur with a minimum number of days of absence from participation of three weeks (Sabesan *et al*., 2016), while nearly 80.0% of recurrences were sustained within two months of the player returning to play (Archbold, Rankin, Webb, Nicholas, Eames *et al*., 2018).

The recurrent injuries sustained across the season were moderate in nature, resulting in players losing 8 to 28 days of participation. In the present study, a positive relationship was reported between the nature of injury (overuse or trauma) and recurring injury, and between the type of injury and recurring injury.

While not common amongst the backs, the forwards were more prone to sustaining upper limb injuries, possibly due to the contact nature of the game (Ball *et al.*, 2020; Hillhouse, 2013). In contrast, backs sustained more concussions, while performing high-speed tackles or being tackled in open play (Ball *et al*., 2020; Whitehouse *et al*., 2016). Previous literature showed that lacerations and concussions were sustained due to player-to-player contact instead of player-to-surface contact (Mathewson & Grobbelaar, 2015). Incorrect or poor tackling technique, e.g., faulty head position, could result in a player's head colliding with an opponent's hip leading to concussion or other head and facial injuries (Barrett, 2015; Whitehouse *et al*., 2016). The severity of injury, especially to the head, is concerning, because these players will not only be absent from the sport but, possibly, from their academic commitments as well (Barrett, 2015). The recurrence of injury is often more debilitating and poses an even greater burden and deleterious effect on a player's long-term well-being (Archbold *et al*., 2018). Players might be urgently needed to return to play, therefore, disregarding their full return-to-play protocol (Murias-lozano *et al*., 2022). The incorrect identification of recurrent injuries often results in inaccurate reporting of new and recurrent injuries, so further investigation needs to be conducted on injury recurrence (Cross, 2016). The proper identification of a recurrent injury initially, allows for more effective and individualised intervention and management in order to reduce the likelihood of recurrence (Cross, 2016). Overall, this information provides more insight on potential risk factors and mechanisms of injury, and assists in formulating and implementing sport-specific injury intervention protocols across all playing positions, especially within the university population (Hillhouse, 2013;

Ogaki *et al*., 2020). A possible solution to prevent or reduce the incidence of injury is to perform a preseason medical screening test that includes functional movement screening (FMS) to determine any muscle weakness or asymmetry and imbalance in range of motion, as these are proven to increase the risk of injury (Ogaki *et al.*, 2020).

5.5 Injury Occurrence Based on the Phase of Play

The relationship between injury and match activity is established in the literature (Fuller *et al*., 2020). Numerous studies reported that contact events in matches were the most frequent mechanism of injury (Cruz-Ferreira *et al*., 2018; Fuller *et al*., 2020; Fuller *et al*., 2008; Fuller *et al*., 2017; Murias-lozano *et al*., 2022; Solis-Mencia *et al*., 2019; Whitehouse *et al*., 2016). It is evident that either being tackled or being the tackler is a common mechanism of injury (Moore *et al.*, 2015; Murias-lozano *et al*., 2022). The tackle event, predominantly affecting the tackler, usually accounted for the most injuries, due to the uncontrolled and open nature of play, none of which was position-specific (Hillhouse, 2013; Morkel, 2016; Yeomans, 2020). Tackling, followed by running, rucks and mauls were the most common causes of injury and predisposed players to concussions (Chéradame, Piscione, Carling, Guinoiseau, Dufour *et al*., 2021; Hillhouse, 2013; Morkel, 2016; Ogaki *et al*., 2020; Yeomans, 2020).

Players were more likely to sustain injury, due to contact events during matches than in training, and tackle-related events were the main mechanism of injury (Moore, Ranson, Mathema, 2015). For example, a study on Spanish Rugby Union players reported a staggering 67.4% of injuries sustained in matches that were the result of contact, and that 31.2% of these were associated with tackling (Moore *et al*., 2015; Murias-lozano *et al*., 2022). In the present study, contact events were responsible for the majority of match injuries (91.1%) as opposed to non-contact events (8.9%), which was similar to that reported in previous research (Fuller *et* *al*., 2017; Hillhouse, 2013; Moore *et al.*, 2015; Murias-lozano *et al*., 2022; Tucker, Raftery, Fuller, Hester, & Kemp *et al.*, 2017; Yeomans *et al*., 2018). During the 2011 Varsity Cup season, 9.0% of injuries were reported as non-contact injuries (Hillhouse, 2013). Generally, non-contact injuries were predominantly running-related injuries (Moore *et al*., 2015; Whitehouse *et al*., 2016).

Injuries during the Young Guns tournament were sustained across all phases of play and were distributed as follows: tackling (28.7%), collision (13.9%), being tackled (10.9%) and the scrum (9.9%). This was similar to that reported for Spanish Rugby Union players who sustained tackling (21.1%), being tackled (17.2%), collisions (9.5%) and rucking injuries (8.8%) (Murias-lozano *et al*., 2022). However, elite French Rugby Union championship players generally sustained higher incidences of injury with tackling (51.3%), being tackled (17.9%), rucks (14.6%), collisions (13.1%) and mauls (2.1%) (Chéradame *et al*., 2021). Similarly, the results in Australian Rugby Union reported that contact events were responsible for 75.7% of all injuries that were due to being tackled (22.5%), performing a tackle (20.7%) or being part of a collision (19.8%) (Whitehouse *et al*., 2016).

There were notable differences in injuries sustained by forwards and backs based on the phase of play. The backs sustained a greater number of collision (15.4%) and tackling (34.6%) injuries than the forwards (12.2% and 22.4%, respectively). The Young Guns forwards were more likely to sustain injuries due to tackling (22.4%), scrum (20.4%) and collision and ruck (each 12.2%) phases of play. Furthermore, backs were more prone to injuries sustained during the tackling (34.6%), collision (15.4) and being tackled (11.5%) phases of play. These results were similar to those of Varsity Cup forwards and backs, as tackling and collisions accounted for the majority of injuries (Hillhouse, 2013). These results were also similar to those of the majority of studies that identified the tackle as the phase of play which caused the most injury, ranging from Japanese and South African university-level tournaments to elite RWC tournaments (Barrett, 2015; Cruz-Ferreira *et al*., 2018; Fuller *et al*., 2020; Fuller *et al*., 2008; Fuller *et al*., 2017; Hillhouse, 2013; Murias-lozano *et al*., 2022; Ogaki *et al*., 2020; Solis-Mencia *et al*., 2019; Whitehouse *et al*., 2016). The high frequency of completed tackles could be the reason why there was a high incidence of tackle injuries (Whitehouse *et al*., 2016). Forwards were exposed to more tackles than backs (12.8 and 7.6 tackles, respectively), and more high velocity impacts than backs (Paul *et al*., 2022). The tackle velocity and force of impact were important factors that considerably influenced the risk of injury (Brooks & Kemp, 2011; Whitehouse *et al*., 2016). More recent observational studies reported that front-on tackles, a higher point-of-contact on the ball carrier, tackles when players were off-balance and head-to-head contact were factors that predisposed players to increased risk of injury (Stokes, Locke, Roberts, Henderson, & Tucker *et al*., 2021; Tucker *et al*., 2017). In addition, two or more teammates simultaneously attempting to tackle was associated with a greater risk of injury, therefore, tackling should preferably be limited to only two players in order to potentially reduce the risk of injury (Strauss, 2013). Furthermore, it is proposed that players should reduce their speed before making contact or attempt to make 'passive/non-dominant tackles' (Stokes *et al*., 2021). The significant relationship between tackling and injury also indicated the need for–drastic improvement in tackling skills and techniques, starting with younger or inexperienced players, for safer participation in the sport (Ogaki *et al*., 2020; Tierney, Denvir, Farrell, & Simms, 2018).

Reporting more specific injury mechanisms are made possible through video analysis, and can determine whether newly implemented laws and interventions were effective in injury prevention (Moore *et al*., 2015). Although amendments to the law and technique regarding the tackle aim to prevent head-contact and, ultimately, protect against tackle injury, a recent study showed that introducing a lowered maximum tackle height law was associated with an increased incidence of concussions among tacklers (Stokes *et al*., 2021; Tucker *et al*., 2017).

5.6 Injury Occurrence Based on the Playing Position

A player's position is an uncontrollable risk factor that is fundamental when constructing injury-prevention programmes, due to the association between injury profile and playing position (Brooks & Kemp, 2011; Chiwaridzo, Masunzambwa, Naidoo, Kaseke, Dambi *et al*., 2015). The demands of each playing position were responsible for the injury characteristics (Ogaki *et al*., 2020). Although forwards and backs were both equally vulnerable to injury, forwards were at higher risk, due to frequent exposure to collisions, constantly being in contention for ball possession and having an increased body mass index (Chiwaridzo *et al*., 2015; MacQueen & Dexter, 2010; Read, Weaving, Phibbs, Darrall-Jones, Roe *et al*., 2017). A systematic review found that forwards engaged in an average of 55 tackles per match, while backs only engaged in 29 tackles (Kaux *et al*., 2015).

In the 2007, 2011, 2015 and 2019 RWC injury surveillance literature, the match injury incidence for backs was higher than forwards (Fuller *et al*., 2020). However, at university-level, forwards had higher injury rates (63.4%) compared to backs (36.6%) (Hillhouse, 2013). In contrast, a meta-analysis found no significant difference in overall match-injury incidence between forwards (78.0 injuries/1000 match-hours) and backs (76.0 injuries/1000 match-hours) (Williams *et al*., 2021). Forwards usually sustained more shoulder and ankle injuries, while backs had more thigh and knee injuries (Brooks & Kemp, 2011; Ogaki *et al*., 2020). During the 2011 Varsity Cup tournament, similar injury profiles were reported for the front row players (Hillhouse, 2013). Interestingly, the second-row players sustained more injuries than other playing positions, followed by the props, inside backs and loose forwards (Hillhouse, 2013). Loose forwards, props, wings and centres were most frequently substituted, due to injury (Kaux *et al*., 2015).

The incidence of injury by the Young Guns players was similar to that of the Varsity Cup Koshuis competition and amateur Namibian rugby players, which resulted in the back row, centres and outside backs experiencing a greater number of injuries (Barrett, 2015; Morkel, 2016). In the literature, half-backs had the highest risk of concussion, however, for Young Guns players, the fullback position had the highest risk of concussion injury (Chéradame *et al*., 2021). The number 8 position was more susceptible to shoulder/clavicle injury, specifically sprain/ligament injury. Neck and shoulder injuries were significantly higher in centres, which was similar to the Young Guns players, as the inside centres and hookers sustained a higher number of neck and shoulder injuries (Brooks & Kemp, 2011). The players, who came into the match as substitutes, generally sustained a smaller number of injuries (6.9%), most likely due to shorter match-exposure time, compared to players who were in the starting fifteen.

The injury surveillance conducted within the Young Guns tournament highlights various risk factors, based on injury characteristics for playing group and position and, hopefully, will assist in ensuring player wellbeing through the implementation of position-specific intervention protocols (Kaux *et al*., 2015; Ogaki *et al*., 2020). Certain playing positions were more prone to injury, due to the unique positional demands and duties (Barrett, 2015; Leahy *et al*., 2022). Front-row forwards sustained cervical injury, due to the impact forces in the scrum and hyper-flexion injury in a collapsed scrum (Brooks & Kemp, 2011; MacQueen & Dexter, 2010). Halfbacks were more predisposed to hamstring injury through repetitive kicking, while the inside backs were more prone to injury while tackling, due to a significantly higher tackle count compared to other playing positions (Brooks & Kemp, 2011).

5.7 Injury Occurrence Based on the Playing Quarter of the Game

The time in a match when an injury occurred is recorded according to quarters, i.e., the first quarter is 0 – 20 minutes, the second quarter is 21 – 40+ minutes (making up the first half of a match), the third quarter is 41 – 60 minutes, and the fourth quarter is 61 – 80+ minutes (making up the second half of a match) (Barrett, 2015; Mirsafaei Rizi *et al*., 2017).

The majority of injuries sustained during the Young Guns tournament occurred in the second half of matches (47.5%) in comparison to the first half (30.7%). The highest injury incidence was sustained in the third quarter (26.7%), with the remaining injuries sustained in the first, second and fourth quarters being 7.9%, 22.8% and 20.8% respectively. These findings were similar to those reported in previous studies (Lazarczuk, Love, Cross, Stokes, Williams *et al*., 2020; Yeomans, Kenny, Cahalan, Warrington, Harrison *et al*., 2021; Leahy, Kenny, Campbell, Warringon, Purtill *et al*., 2022; Murias-lozano *et al*., 2022). The forwards had a slightly higher prevalence of injury during the first half, whereas the backs were significantly more affected during the second half of matches (Fuller *et al*., 2020; Hillhouse, 2013).

It is well-established in the literature that injuries were least likely to occur in the first quarter of a match (Morkel, 2016; Solis-Mencia *et al*., 2019), whereas the number of injuries were highest in the third and/or fourth quarters of a match (or the second half) (Barrett, 2015; Hillhouse, 2013; Morkel, 2016; Solis-Mencia *et al.*, 2019; Wekesa, Asembo, & Njororai, 1996). In the Varsity Cup Koshuis competition, 29.9% and 27.5% of injuries were sustained during the first and second quarters, respectively (Barrett, 2015). Similarly, in the 2011 Varsity Cup tournament, 15.0%, 26.7%, 24.8%, 30.7% of injuries were recorded over the respective four quarters (Hillhouse, 2013). A major concern is that a staggering 63.0% of tackle-related head injuries occurred in the final quarter (Tierney *et al*., 2018). A systematic review documented that Achilles tendon injuries were more prevalent in the first half, and ankle ligament injuries in the second, while 58.0% of knee injuries were sustained in the second half, and 32.0% of these in the final quarter (Kaux *et al*., 2015).

Documenting injury according to its chronological occurrence in the game is beneficial when determining how fatigue affected the rate of injury (Viviers *et al*., 2018). The number of injuries tended to increase as the match progressed, with the more important periods of play being the second and fourth quarters (Kaux *et al*., 2015; Viviers *et al*., 2018). Potential risk factors that exposed players to injury in the third quarter (or second half) included the lack of physical conditioning, incomplete warm-up, incomplete recovery during half-time, and lowered concentration or inability to adapt to the playing intensity after the half-time break (Barrett, 2015; Hillhouse, 2013; Morkel, 2016; Solis-Mencia *et al*., 2019). Moreover, fatigue reduced tackling proficiency, especially at the end of the game or during extra time (Tierney *et al*., 2018). Implementing techniques to refocus players' concentration post-half-time was important, due to the heightened risk of injury through reduced cognitive capacity (Solis-Mencia *et al*., 2019). At the professional level of play, players' tackling technique deteriorated as matches progressed (Lazarczuk *et al*., 2020). This signalled a relationship between tackling injuries and fatigue development, particularly towards the latter stages of the match (Solis-Mencia *et al*., 2019; Tierney *et al*., 2018). Therefore, players should have the ability to tolerate the physical demands of the match and endure multiple contact situations safely and effectively, especially at university-level (Solis-Mencia *et al*., 2019).

5.8 Injury Occurrence Based on Foul Play

Nearly 20.0% match injuries sustained by the Young Guns players were the result of foul play. The contact phases of the game, such as the tackle or being tackled, resulted in the majority of the injuries that were due to either foul play or dangerous play (Matthewson & Grobbelaar, 2015). In 50.0% of injuries due to foul play, players neglected to use protective equipment. In addition, injuries due to foul play mostly affected the head and neck/cervical region, and often led to concussion. Specifically, the number 8, left wing and inside centre playing positions were negatively impacted by foul and dangerous play.

Foul play increased the risk of injury and takes on many forms, including dangerous play or misconduct (Chalmers *et al*., 2011; Morkel, 2016). Therefore, it is important to coach players on the laws of the game (Chalmers *et al*., 2011; Morkel, 2016). To assist in identifying foul play and to promote player safety, World Rugby makes use of television match officials (TMO) (Stoney & Fletcher, 2021). High tackles, tip tackles, shoulder charges and challenging a player in the air are considered illegal tackles, because they carry a significantly greater risk of injury, specifically concussion (Stokes *et al*., 2021). One study found that around 13.0% of injuries, more specifically head injuries and muscular contusions, were a result of foul play (Kaux *et al*., 2015). Foul play, such as high and late tackles, increased the risk of severe injuries and was associated with 42.0% of concussions, and 12.5% of fractures and dislocations (Bleakley *et al*., 2011). In another study, 55.2% of injuries were due to foul play, with 6.9% of these injuries considered dangerous play (Solis-Mencia *et al*., 2019).

World Rugby has adjusted and implemented amendments to the laws, as well as implemented educational initiatives to reduce injuries, e.g., the laws of scrum engagements (including 'crouch-touch-pause-engage' before scrum engagement) and tackling (banning high- and spear-tackles) (Lipert *et al*., 2021; Posthumus, 2008). Although changes to the laws have the potential to prevent injury, there is also a need to involve relevant stakeholders for implementing the changes in order to reduce the incidence of injury (Stokes *et al*., 2021). Therefore, it is important to document the phase of play in which injury occurred and whether it was due to dangerous or foul play in order to determine if coaching methods, aligned to the amended laws, were effective (Hillhouse, 2013).

5.9 Injury Occurrence Based on the Field of Play

In the present study, the majority (41.6%) of injuries occurred while playing in the opposition half. Most of the injuries were due to tackling and collisions. A reason for this might be due to the team applying defensive pressure through constantly tackling, while in the opposition-half and own-22 areas.

There is little-to-no information with regard to injury and the specific part of the field in which it occurred. However, Wekesa (1996) reported that 53.0% of injuries occurred in the defensive part of the field, while 46.0% were in the offensive half. Therefore, more injuries were sustained in the defensive half of the field, which is important information concerning awareness and proper preparation for injury prevention (Wekesa *et al*., 1996).

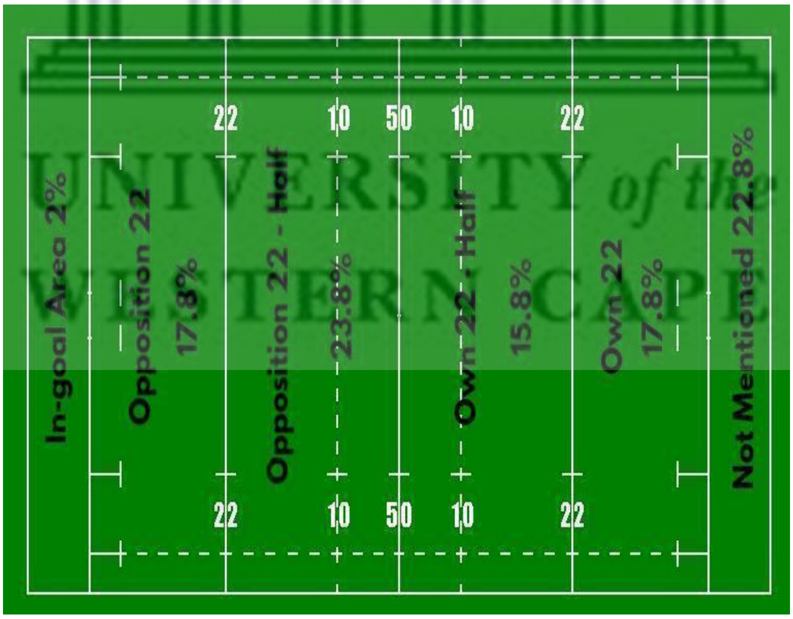

Figure 5.1: Proportion of injury sustained during the match based on the area of the field where injury occurred.

5.10 Injury Occurrence Based on Protective Equipment

Many Young Guns players still did not make use of protective equipment, which could have been responsible for nearly 35.0% of injuries. The majority of injuries sustained in a match occurred while players were using a mouth-guard. The use of mouth-guards, shoulder padding or headgear, as protective equipment, still resulted in players being injured (43.6%). The Young Guns players failed to wear appropriate protective apparatus. In the majority of instances, where no protective equipment was worn, players sustained severe injury, resulting in more than 28 days absence from participation. Either tackling or being involved in a collision with no protective equipment caused injury.

The governing bodies, World Rugby and South African Rugby Union, recommended a list of approved protective equipment to assist in preventing injury (Strauss, 2013). Through the years, there has been a noticeable increase in the use of protective equipment, e.g., head gear, mouth-guards, shoulder pads and strapping, to reduce impact and injury in Rugby Union (Strauss, 2013; Barden, Bekker, Brown, Stokes, & McKay, 2020; Daly, Blackett, Pearce, & Ryan, 2022; Sărăndan, Negru, Marşavina, Mihuţa, & Şerban, 2023).

Wearing scrum caps reduced the risk of scalp and ear injuries, however, the players were still at 23.0% increased risk of injury, as headgear did not prevent the chance of concussion (MacQueen & Dexter, 2010; Morkel, 2016). During the 2019 Currie Cup competition, 40.0% of players who sustained a time-loss injury, and four of the eleven who sustained a concussion, made use of a mouth-guard. It is difficult to draw any definite conclusion about the relationship between injury susceptibility and the use of mouth-guards (Starling *et al.*, 2020).

To manage the frequent, high-impact forces in a match, players used a World Rugby-approved attenuating device, i.e., shoulder padding that covers the clavicles (MacQueen & Dexter, 2010; Usman, McIntosh, Quarrie, & Targett, 2015). However, previous studies showed that shoulder pads were ineffective in absorbing or reducing the impact forces on the shoulders when making a tackle, as these forces were only reduced by 3.0% (Barrett, 2015; Sinclair, 2009; Strauss, 2013; Usman *et al*., 2015). Starling *et al*. (2020) noted that in 13.0% of injuries, strapping was worn on the site of injury, with the majority of injuries located at the ankle. There was no clear evidence that using strapping or taping helped prevent injuries (Strauss, 2013).

Educating players on the importance of proper technique, physical conditioning and the benefits of wearing protective equipment has proven to reduce injuries in rugby (Bahr & Krosshaug, 2005; Barnes *et al*., 2017; Daly *et al*., 2021; Mahaffey, Owen, Owen, van Schalkwyk, Theron *et al*., 2006; Roberts *et al*., 2017; Strauss, 2013). Preventing injuries, such as concussion, especially within a university population, should be prioritised in order to maintain the cognitive abilities of the players who were also students in an academic environment with tremendous mental workload and stress (Barrett, 2015). Players might engage in more reckless play, due to perceived protection from their equipment, resulting in a greater risk of concussion (MacQueen & Dexter, 2010; Morkel, 2016). Previous literature illustrated that the use of headgear and mouth-guards provided inadequate protection against concussions, even though they were proven effective against lacerations and dental injuries (Barrett, 2015).

Therefore, further research into the effective use of protective gear or alternative equipment is warranted (Barrett, 2015; Sabesan *et al*., 2016). Rugby, compared to other full-contact sports, only requires players to wear mouth-guards (Sabesan *et al*., 2016). Therefore, advocacy for greater safety not only in Rugby Union, but also Varsity Cup rugby is warranted in order to mandate increased use of protective gear (Sabesan *et al*., 2016).

5.11 Predicting the Risk of Injury Based on Playing Position

The information on the Young Guns players and their injuries was used to form a predictive model, in an attempt to determine the risk of injury for specific positions. This was due to the high incidence of injury reported in the literature, which rarely examined the predictors of injury (Bjelanovic, Mijatovic, Sekulic, Modric, Kesic *et al*., 2023).

In the present study, forwards and backs were at greater risk of injury to the anterior thigh, while playing in the opposition-22 and halfway line of the field, during either the first or second quarters, even while wearing protective headgear. Also, the number 8 position was more likely to sustain injury in the second quarter of the match compared to the rest of the players. Bjelanovic *et al*. (2023) also predicted that forwards, in general, were at higher risk of sustaining injury, especially the flankers (Bjelanovic *et al*., 2023). The most evident factor used as an injury predictor was player group, as forwards generally presented with a higher incidence of injury than backs (Bjelanovic *et al*., 2023). Furthermore, a previous study confirmed that injury history and playing while injured, were additional risk factors that could be used as predictors of future injuries (Bjelanovic *et al*., 2023).

5.12 Strengths and Limitations of the Study

5.12.1 Study Strengths

- This is the first ever whole-population-based study to focus on the Varsity Cup Young Guns rugby players, presenting an in-depth, detailed description of injuries that were sustained during the 2022 playing season.
- This study, based on the distribution and determinants of injury, is the first to provide valuable insight to injuries sustained by university student-athletes. The assessment of

additional parameters was novel and unique, and have not been investigated in previous studies that included other student rugby players.

- The present study is the first to apply regression analysis to predict injury risk based on playing position in university rugby players.
- In this study, the injuries sustained during the Young Guns competition were diagnosed and reported by qualified healthcare professionals, including medical doctors, physiotherapists and/or biokineticists who used a standardized and validated injury report form that contributed to the quality of data collection.

5.12.2 Study Limitations

- There is great variability in the anthropometric and aerobic fitness characteristics provided by the various universities that was also incomplete, which resulted in a lack of descriptive information that negatively impacted the interpretation of the data. Three of the ten institutions competing in the Young Guns tournament declined to submit injury data, which likely compromised the power of the study.
- The current study is limited to studying the event or phase of play causing injury and not the precise injury mechanisms.
- In the majority of injury surveillance projects, individual exposure hours was not accounted for, but rather only team exposure hours for 15 players over 80 minutes of play. This is potentially incorrect, as it does not consider players who played for less than 80 minutes, players who played during periods of extra time, players who were in the "sin-bin" or substitute players, e.g., due to head injury assessment or as a blood replacement. The players' actual playing times were not adequately recorded, thereby, misrepresenting the

actual exposure times. Therefore, the injury incidence might be in error, due to a lack of specific information on exposure time.

5.13 Conclusion

There was a high incidence of injury in rugby players playing in the Varsity Cup Young Guns competition in the 2022 season, which supports the previously stated hypothesis. The incidence of injury was greater in matches than during training, and the overall incidence of match injuries for backs was greater than that for forwards. It has correctly been hypothesized that the forward players will sustain more injuries to their upper body, while the backs will sustain more injuries to their lower body. However, flankers were not the most injury-prone position in the study, but rather the number 8, inside centre and full back positions who had the highest incidence of injury. In agreement with the hypothesis, the shoulder accounted for the most frequent site of injury, followed by the head and ankle, while sprain or ligament injury, concussion and contusion were the most common types of injuries sustained by rugby players. The severity of injury was mostly moderate in nature resulting in an absence from play of 8 to 28 days. Potential risk factors of injury included illegal or dangerous play, playing in the second half of the match (more specifically the third quarter of the match), and playing in the offensive part of the field (more specifically between the opposition-22 and halfway line). It was correctly hypothesized that the tackling phase of play will contribute the most to player injury. The high incidence of injury in university rugby highlights the need to address, build on, and expand the current knowledge (educationally and preventatively) which will form the basis of injury prevention strategies, with the aim of ensuring and promoting player health and knowledge amongst university rugby players in South Africa. Therefore, this study advocates for the implementation of new and standardised injury surveillance systems within Varsity Cup rugby competitions.

5.14 Recommendations

The following recommendations, including components such as acquiring adequate baseline anthropometric and physical fitness testing scores, capturing the precise mechanism of injury, and documenting the precise exposure hours, are important aspects to investigate when addressing the limitations of the current study. According to the theoretical model used in this study (The TRIPP model), only steps one (injury surveillance) and two (establishing the aetiology and mechanisms of injury) have been completed. Therefore, the following recommendations are aligned with the remaining four stages of the model to assist in injury prevention.

- There is a need for a standardized injury data recording sheet across all teams, for recording the baseline anthropometric and physical fitness results of the university rugby players.
- Due to the consistently increasing rate in match injury and the improving level of professionalism in the sport, there is a desperate call for an injury surveillance system that is well suited and broadly accepted for university rugby.
- Applying video analysis is essential in providing valuable insight when investigating specific factors in contact events leading up to injury, which could be used to formulate interventions and establish the effectiveness of techniques and rule amendments. However, this is mostly used to study the mechanisms of injury in contact situations, especially those leading to concussion.
- The exposure rates in the current study are calculated collectively for the entire cohort, and are not individualised to specific training and match exposure data. Therefore, future

research needs to include training and match exposure data, as well as match and training workload data. Admittedly, the use of global positioning system (GPS) tracking of players could be used to accurately record individual player's training and match exposure time and training workload.

- Continued injury surveillance should be undertaken to determine the efficacy of the predictors, as well as the changes in these predictors over time. The addition of a screening tool, such as functional movement screening (FMS), could be beneficial to all teams, as it considers fundamental movements as an assessment of function and risk of injury. Such data provides a quantifiable objective measure to monitor potential injury risk, and assist in designing specific corrective exercises to minimize the risk.

5.15 Summary

Rugby is associated with a high risk of injury, with amateur players more prone to injury in comparison to professional players. The physical nature of the game allows for a high-risk of injury compared to other non-contact sporting codes. The study aimed to determine the incidence of injury among male rugby players participating in the FNB Varsity Cup Young Guns tournament. The study also aimed to determine the association between anthropometric characteristics and playing position, and to predict the risk of injury based on playing position.

The injury incidence for all players was 9.5 injuries/1000 player-hours. The injury incidence for all players during matches was 136.5 injuries/1000 match hours, whereas during training it was 0.6 injuries/1000 training-hours. Overall, backs sustained a relatively greater incidence of injuries (9.9 injuries/1000 player-hours) than forwards (9.2 injuries/1000 player-hours). A statistically significant association was found between a rugby playing position and the phase of play that caused the injury.

It is recommended that future research looks into ensuring adequate baseline anthropometric and physical fitness testing scores are recorded, the precise mechanism of injury is captured, and the potential relationship between match and training exposure hours and injury is investigated. Furthermore, a consistent injury surveillance programme should be established within the Varsity Cup competition and the results of such research used to assist, maintain and improve current injury prevention strategies and further develop and implement new strategies.

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APPENDIX A: INFORMATION LETTER

UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa
Tel: +27 21-959 2350 *E-mail:* 3634241@myuwc.ac.za

INFORMATION SHEET

Project Title: Determining the incidence, risk factors and predictors of injury among male FNB Varsity Cup rugby players in South Africa

What is this study about?

This is a research project being conducted by Renaldo Solomons, a Master's candidate at the University of the Western Cape. I am inviting you to participate in this research project as you will form part of a valuable study which will be used to determine injury incidence data among amateur male Varsity Cup rugby players.

What will I be asked to do if I agree to participate?

You will be asked to either complete an injury questionnaire detailing your injuries or to give permission for the researcher to use the information gathered on you by the team's medical personnel. With the inclusion of the results of your baseline fitness testing.

Would my participation in this study be kept confidential?

The research undertaken strives to protect your identity and the nature of your contribution. To ensure your anonymity, data will be coded alpha-numerically, instead of using your name, and only the researcher will have access to the identification key. To ensure your confidentiality, all your personal information will be securely kept in a password-protected computer folder in the research supervisors' office.

What are the risks of this research?

There may be some risks associated with participating in this research study. Much like any assessment, there are risks which can be described as both expected and unexpected. Possible expected risks of an emotional and psychological nature may include feeling self-conscious or embarrassed due to having fears of possible negative outcomes, when reporting injuries sustained. Possible unexpected risks refer to physical aspects, and may include discomfort during assessments. These risks will be minimized to ensure the safety of participants.

What are the benefits of this research?

This research is not designed to help you personally, but the results may help the researcher learn more about the incidence of injuries among amateur male rugby players. In future, other people might benefit from this study through improved understanding of the prevalence of these injuries in order to develop appropriate preventative measures.

Do I have to be in this research and may I stop participating at any time?

Your participation in this research is completely voluntary. You may choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.

What if I have questions?

This research is being conducted by Renaldo Solomons of the Department of Sport, Recreation and Exercise Science at the University of the Western Cape. If you have any questions about the research study itself, please contact:

Renaldo Solomons
3634241@myuwc.ac.za

Should you have any questions regarding this study and your rights as a research participant or if you wish to report any problems you have experienced related to the study, please contact:

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This research has been approved by the University of the Western Cape's Biomedical Research Ethics Committee.
(REFERENCE NUMBER: BM21/5/15)

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APPENDIX B: CONSENT FORM

UNIVERSITY OF THE WESTERN CAPE

Private Bag X 17, Bellville 7535, South Africa
Tel: +27 21-959 2409 **E-mail:** 3634241@myuwc.ac.za

CONSENT FORM

Title of Research Project: **Determining the incidence, risk factors and predictors of injury among male FNB Varsity Cup rugby players in South Africa**

The study has been described to me in a language that I understand. My questions about the study have been answered. I understand what my participation will involve and I agree to participate of my own choice and free will. I understand that my identity will not be disclosed to anyone. I understand that I may withdraw from the study at any time without giving a reason and without fear of negative consequences or loss of benefits.

Participant's name: ……………………………………....

Participant's signature: ……………………………..........…….

Date: ………………….....................………

APPENDIX C: DATA RECORDING SHEET

UNIVERSITY OF THE WESTERN CAPE

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Tel: +27 21-959 2409 **E-mail: 3634241@myuwc.ac.za**

Rugby Injury Questionnaire

Injury Report Form for Rugby Union

(Team) Player-code: .... Date:....................

1A. Date of injury: ....1B. Time of injury (during match): ....

2. Date of return to full participation: ....

3. Playing position at the time of injury: .... ☐ Not applicable

4. Injured body part:

☐ head/face	☐ upper arm	☐ anterior thigh
☐ neck/cervical spine	☐ elbow	☐ posterior thigh
☐ sternum/ribs/ upper back	☐ forearm	☐ knee
☐ abdomen	☐ wrist	☐ lower leg/ Achilles tendon
☐ low back	☐ hand/finger/ thumb	☐ ankle
☐ sacrum/pelvis	☐ hip/groin	☐ foot/toe
☐ shoulder/clavicle		

5. Side of body injured: ☐ left ☐ right ☐ bilateral ☐ not applicable

6. Type of injury:

☐ concussion (with or without loss of consciousness)	☐ sprain/ ligament injury	☐ haematoma/contusion/ bruise
☐ structural brain injury	☐ lesion of meniscus, cartilage or disc	☐ abrasion
☐ spinal cord compression/ transection	☐ muscle rupture/ strain/tear/cramps	☐ laceration
☐ fracture	☐ tendon injury/ rupture/ tendinopathy/ bursitis	☐ nerve injury
☐ other bone injury		☐ dental injury
☐ dislocation/subluxation		☐ visceral injury

☐ other injury (please specify): ....

7. Diagnosis of injury (text or code): ....

8. Has the player had a previous injury of the same type at the same site (i.e. this injury is a recurrence)?

☐ no ☐ yes

If YES, specify date of player's return to full participation from the previous injury: ....

9. Was the injury caused by: ☐ overuse ☐ trauma?

10. Did the injury occur during: ☐ training ☐ match?

11. Was the injury caused by contact? ☐ no ☐ yes

If YES, specify the activity: ☐ tackled ☐ tackling ☐ maul ☐ ruck ☐ lineout ☐ scrum ☐ collision ☐ other

12A. Did the referee indicate that the action leading to the injury was a violation of the Laws?

☐ no ☐ yes

12B. Did the referee indicate that the action leading to the injury was dangerous play (Law 10.4)?

☐ no ☐ yes

APPENDIX D: ETHICS CLEARANCE LETTER

UNIVERSITY *of the* WESTERN CAPE

60 YEARS *of hope, action & knowledge*

13 August 2021

Mr R Solomons
Sport, Recreation and Exercise Science
Faculty of Community and Health Sciences

Ethics Reference Number:	BM21/5/15
Project Title:	Determining the incidence, risk factors and predictors of injury among male FNB Varsity Cup rugby players in South Africa.
Approval Period:	13 August 2021 – 13 August 2024

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project.

Any amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report annually by 30 November for the duration of the project.

Permission to conduct the study must be submitted to BMREC for record-keeping.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

Director: Research Development
University of the Western Cape
Private Bag X 17
Bellville 7535
Republic of South Africa
Tel: +27 21 959 4111
Email: research-ethics@uwc.ac.za

NHREC Registration Number: BMREC-130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

APPENDIX E: LETTER OF PERMISSION TO THE HEAD OF VARSITY CUP

FACULTY of COMMUNITY AND HEALTH SCIENCES
UNIVERSITY of the WESTERN CAPE

DEPARTMENT OF SPORT, RECREATION AND EXERCISE SCIENCE
University of the Western Cape, Robert Sobukwe Avenue, Bellville 7535
(021) 959 2350 OR 021 959 2409
ntsoli@uwc.ac.za or dobowers@uwc.ac.za

10 September 2021

Xhanti-Lomzi Nesi
Varsity Sports Manager
ASEM VARSITY SPORTS (PTY) LTD

Dear Mr. Nesi

Re: UWC Research within the FNB Varsity Cup Rugby

This letter pertains to the request for permission by Mr. Renaldo Solomons, a Master's student (Student Number. 3634241) at the University of the Western Cape, to conduct research towards his MSc Degree in Biokinetics in the FNB Varsity Cup Rugby Tournament in 2022. This letter of permission is requested from the ASEM Varsity Sports Board in order to gain access to the relevant rugby teams and players who participate in the Varsity Cup at each institution.

The following information or documents are submitted to ASEM Varsity Sports Board, which serves to explain the request for permission to conduct the research, namely:

Research Title: Determining the incidence, risk factors and predictors of injury among male FNB Varsity Cup rugby players in South Africa.

Purpose of the Research: To determine the incidence and risk factors of injury in male Varsity Cup rugby players and to predict the risk of injury based on playing position.

Population for the Research: The ten amateur male Varsity Cup rugby teams participating in the 2022 season.

The partners or organisations that will be involved in the research are the ASEM Varsity Cup Rugby and the Department of Sport, Recreation and Exercise Science, UWC.

The research procedures, plans and timeframes include the following:

- The ten Varsity Cup rugby teams will be recruited for the research. Arrangements will be made with the Registrar of each tertiary institution that has a Varsity Cup team to obtain permission to access the rugby players. Thereafter, the information and details of the study will be communicated to the players, both verbally and in writing. All players will be informed that their participation in the study is voluntary and that consent is required in writing. Consequently, once player consent has been obtained, then the injury data required for the study will be obtained from the appropriate health practitioner (e.g. physiotherapist).

University of the Western Cape. Private Bag X17. Bellville 7535. South Africa.

DEPARTMENT OF SPORT, RECREATION AND EXERCISE SCIENCE
University of the Western Cape, Robert Sobukwe Avenue, Bellville 7535
(021) 959 2350 OR 021 959 2409
ntsoli@uwc.ac.za or dobowers@uwc.ac.za

- There will be no impact or burden on specific players, because of the study. Rather the health practitioner or physiotherapist will provide the required research data, preferably in an electronic format that is password-protected and anonymous, without disclosure of the players' identities. In most instances, this data is already captured electronically at most tertiary institutions and, so, will not be burdensome to the practitioner with regard to sharing the data with the researcher.

- The research data will be used primarily for the degree purposes of Mr. Renaldo Solomons, who will be conducting the research. In addition, the research data is planned to be published in peer-reviewed journals of the Department of Higher Education and Training (DHET). The publications are planned for submission in July – December 2022.

- The intention is to use the research information to positively impact the health and wellness of Varsity Cup rugby players. The research outcomes are intended to produce extensive information on the incidence of injuries at Varsity Cup level in order to support the rugby coaches and players and minimize the risk of injuries, as well as to enable more players to become available for competition and to more competitive during the tournament.

- The study data collection period will run from January until June 2022, i.e., for the full duration of the FNB Varsity Cup Tournament.

Attached is the ethics letter of approval from the Biomedical Research Ethics Committee at the University of the Western Cape granting approval for the research to be conducted.

I hope that the information supplied is sufficiently informative and appropriate for your purposes. Nevertheless, I am willing to provide any additional information, as may be requested by Varsity Sports Board in order to support our request.

Thank you for your consideration in this matter, and we look forward to your reply at your earliest convenience.

Yours sincerely

Lloyd Leach
Associate Professor
+27-21-959-2653
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082-200-6987
lleach@uwc.ac.za

APPENDIX F: LETTER OF APPROVAL FROM THE HEAD OF VARSITY CUP

07 February 2022

To whom it may Concern
Dear Madam/Sir

Confirmation of Research Approval for Mr Renaldo Solomons

This letter pertains to the request for permission by Mr. Renaldo Solomons, a Master's student (Student Number. 3634241) at the University of the Western Cape, to conduct research towards his MSc Degree in Biokinetics in the FNB Varsity Cup Rugby Tournament in 2022.

This letter serves to provide Mr Solomons with official approval for the proposed research project following the Varsity Cup Board meeting on 01 February 2022.

The Varsity Cup Board has agreed that the research may be conducted on the FNB Varsity Cup Young Guns Tournament. Confirmation of the approval will be sent to all universities.

If you have any queries, please feel free to contact me.

Xhanti-Lomzi Nesi
Head of Varsity Cup
Nesi@asem.tv
[tel]: 021 418 7646

www.varsitysportsSA.com
157-161 Loop Street, Cape Town, 8001 | 021 418 7845/7646
Director: JF. Pienaar (Chairman)
(VAT Reg. 4670261488)

APPENDIX G: STROBE-SIIS GUIDELINES

Appendix 3: STROBE-SIIS (Sports Injury and Illness Surveillance) Statement 1.0—Checklist of items for the reporting of observational studies on injury and illness in sports

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension +	Source of rationale for item from the consensus statement and where to find further details
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract		
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	SIIS-1.1. Include information on the sport, athlete population (sex, age, geographic region) and level of competition. SIIS-1.2. Include the duration of observation (e.g. one season, one year, multiple years).	SIIS-1.1. 'Study population characteristics' SIIS-1.2. 'Capturing and reporting athlete exposure'
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported		
Objectives	3	State specific objectives, including any pre-specified hypotheses	SIIS-3.1. State whether study was registered. Identify the registration number and database used. SIIS-3.2. State the specific purpose of your study (e.g. to describe the injury burden associated with Olympic level rowing)	SIIS-3.1. 'Reporting guidelines—STROBE Sports Injury and Illness Surveillance (STROBE-SIIS)' SIIS-3.2 Throughout consensus statement
Methods				
Study design	4	Present key elements of study design early in the paper	SIIS-4.1. Clearly specify which health problems are being observed.	SIIS-4.1. 'Defining and classifying health problems'

Bahr R, *et al. Br J Sports Med* 2020;0:1–18. doi: 10.1136/bjsports-2019-101969

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension +	Source of rationale for item from the consensus statement and where to find further details
			SIIS-4.2. State explicitly which approach was used to record the health problem data, including all outcome measures or tools SIIS-4.3. State explicitly which coding system was used to classify the health problems (e.g. OSIICS, SMDCS, ICD, etc.) SIIS-4.4. Where relevant, clearly describe how athletes were categorised. Variables to consider could include the type of athlete and/or sport, the environment in which the sport occurs (e.g. type of course or playing area), the typical duration of the sport, the degree of physical contact permitted in the sport, and the equipment permitted.	SIIS-4.2. 'Data collection methods' SIIS-4.3. 'Classifying sports injury and illness diagnoses' SIIS-4.4. 'Study population characteristics'
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	SIIS-5.1. Describe the location, level of play, dates of observation and data collection methods (i.e. who, what, where). SIIS-5.2. Specify the dates of the surveillance period and how the data were handled when the study covered more than one season/calendar year. SIIS-5.3. Define whether the health problem data were collected prospectively or retrospectively.	SIIS-5.1. 'Study population characteristics' SIIS-5.2. 'Capturing and reporting athlete exposure' SIIS-5.3. 'Capturing and reporting athlete exposure' and 'Data collection methods'

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension +	Source of rationale for item from the consensus statement and where to find further details
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	SIIS-6.1. Define the population of athletes and how they were selected and recruited.	SIIS-6.1. 'Data collection methods' and 'Study population characteristics'
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case		
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	SIIS-7.1. Justify why you measured your primary and secondary outcomes of interest in the specific way chosen. SIIS-7.2. Describe the method for identifying your health problem outcome of interest.	SIIS-7.1. 'Defining and classifying health problems' SIIS-7.2. 'Defining and classifying health problems'
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe	SIIS-8.1. Specify who collected/reported the data for the	SIIS-8.1. 'Classifying sports injury and illness diagnoses' and 'Data collection methods'

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension +	Source of rationale for item from the consensus statement and where to find further details
		comparability of assessment methods if there is more than one group	study and their qualifications (e.g. qualified doctor, data analyst, etc.). SIIS-8.2. Specify who coded the data for the study and their qualifications (e.g. qualified doctor, data analyst, etc.). In many instances, this will not be the same as SIIS-8.1. SIIS-8.3. Specify the direct methods used to collect the data, and the use of physical documents or an electronic tools. If extracting information from existing sources, specify the data source. SIIS-8.4. Specify the timing of and window for data collection (e.g. day health problem occurred or following day). Specify the frequency of data collection (e.g. daily, weekly, monthly). SIIS-8.5. Report the duration of surveillance (e.g. tournament, season, whole year, playing career).	SIIS-8.2. 'Classifying sports injury and illness diagnoses' SIIS-8.3. 'Data collection methods' SIIS-8.4. 'Relationship to sports activity' and 'Capturing and reporting athlete exposure' SIIS-8.5. 'Relationship to sports activity' and 'Capturing and reporting athlete exposure'
Bias	9	Describe any efforts to address potential sources of bias	SIIS-9.1. Clearly report any validation or reliability assessment of the data collection of tools. SIIS-9.2. Formally acknowledge any potential biases in associated with the data collection method (e.g. self-	SIIS-9.1. 'Data collection methods' SIIS-9.2. 'Data collection methods'

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension +	Source of rationale for item from the consensus statement and where to find further details
			report, recall bias, reporting by non-medically trained staff, etc.)	
Study size	10	Explain how the study size was arrived at		
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	SIIS-11.1 Explain in detail how multiple injuries/illness episodes are handled both in individual athletes and across athletes/surveillance periods. SIIS-11.2. Specify how injury severity was calculated.	SIIS-11.1. 'Multiple events and health problems' and 'Subsequent, recurrent and/or exacerbation of health problems' SIIS-11.2. 'Severity of health problems'
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	SIIS-12.1. Specify how exposure to risk has been adjusted for and specify the units (e.g. per participant, per athlete exposure, etc.). SIIS-12.2 Specify how relevant risk measures (incidence, prevalence, etc.) were calculated. SIIS-12.3. When relevant to the study aim, specify how injury burden was calculated and analysed.	SIIS-12.1. 'Capturing and reporting athlete exposure' SIIS-12.2 'Expressing risk' SIIS-12.3. 'Burden of health problems'
		(*b*) Describe any methods used to examine subgroups and interactions		
		(*c*) Explain how missing data were addressed	SIIS-12.4. For studies reporting multiple health problems, state clearly how these were handled (e.g. time to the first injury only, ignoring	SIIS-12.4. 'Multiple health problems' and 'Subsequent, recurrent and/or exacerbation of injury/illness' SIIS-12.5. 'Capturing and reporting athlete exposure'

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension +	Source of rationale for item from the consensus statement and where to find further details
			subsequent return to play and re-injuries, or modelling of all injuries). SIIS-12.5. Explain how/if athletes not included at outset (e.g. those already injured) were handled in the analyses.	
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	SIIS-12.6. In longitudinal studies, it is particularly important to explain how athlete follow-up has been managed. For example, what happened if a player was transferred to another team or has been censored (for those no longer part of the study due to removal during the observation period). Censoring can occur when athletes are removed due to transfer out of the team/study, injury/illness or due to study design.	SIIS-12.6. 'Capturing and reporting athlete exposure'
		(*e*) Describe any sensitivity analyses		
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study—e.g. numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	SIIS-13.1. Clearly state the number of athletes followed-up, the number (and %) of those with the health problem and the number of problems reported among them (a median number of problems per affected athlete could be useful). SIIS-13.2. For studies over multiple seasons/years, report the total	SIIS-13.1. 'Multiple health problems' SIIS-13.2. 'Multiple health problems' and Expressing risk'

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension [+]	Source of rationale for item from the consensus statement and where to find further details
			numbers of health problems for each year and numbers common to each period.	
		(b) Give reasons for non-participation at each stage	SIIS-13.3. Report how athletes removed (e.g. due to transfer of teams or time-out due to injury or illness) impact upon data at key data collection/reporting points, ideally with a flow diagram	SIIS-13.3. Throughout consensus statement
Descriptive data	14*	(a) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders	SIIS-14.1. Include detail on the level of competition being observed (e.g. by age levels, skill level, sex, etc.).	SIIS-14.1. 'Study population characteristics'
		(b) Indicate number of participants with missing data for each variable of interest		
		(c) *Cohort study*—Summarise follow-up time (e.g. average and total amount)		
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	SIIS-15.1. In many observational studies, individuals will sustain more than one health problem over the surveillance period. Take care to ensure descriptive data representing both the number of health problems and the number of athletes affected. It is important to represent effectively both the analysis and reporting of correct units for frequency data, i.e. the % of affected	SIIS-15.1. 'Multiple health problems' and 'Subsequent, recurrent and/or exacerbation of injury/illness'

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension +	Source of rationale for item from the consensus statement and where to find further details
			athletes or the % of injuries, body regions, etc.	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure		
		Cross-sectional study—Report numbers of outcome events or summary measures		
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g. 95% confidence interval). Make clear which confounders were adjusted for and why they were included	SIIS-16.1. Report exposure-adjusted incidence or prevalence measures with appropriate confidence intervals when presenting risk measures. SIIS-16.2. Report details of interest, such as mode of onset	SIIS-16.1. 'Expressing risk' SIIS-16.2. 'Relationship to sports activity', 'Mode of onset—injury', Mode of onset—illness' and 'Classifying the mechanism of injury'
		(*b*) Report category boundaries when continuous variables were categorized		
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses	SIIS-17.1 Report injury diagnosis information, including region and tissue type in tabular form.	SIIS-17.1. 'Defining and classifying health problems'
Discussion				
Key results	18	Summarise key results with reference to study objectives		
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or	SIIS-19.1. Discuss limitations in the data collection and coding procedures adopted, including in	SIIS 19.1. 'Data collection methods' and 'Expressing risk'

Item	Item No	Recommendation from the STROBE Statement	STROBE-SIIS Extension +	Source of rationale for item from the consensus statement and where to find further details
		imprecision. Discuss both direction and magnitude of any potential bias	relation to any risk measures calculated.	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence		
Generalisability	21	Discuss the generalisability (external validity) of the study results	SIIS-21.1. Discuss the generalizability of the athlete study population, and health problem sub-groups of interest, to broader athlete groups.	SIIS-21.2. 'Relationship to sports activity' and 'Study population characteristics'
Other information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based		
Ethics	23		SIIS-23.1. Outline how individual athlete data privacy and confidentiality considerations were addressed, in line with the Declaration of Helsinki.	SIIS-23.1. 'Research ethics and data security'

Note: The STROBE-SIIS checklist with additional sports epidemiology annotations should be used in conjunction with the original STROBE guideline (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

+For brevity, the phrase health problem is used here to encompass both injury and illness.

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

^^ Where there is a blank cell in this column, there are no specific additional reporting requirements for sports injury and illness surveillance over what is already covered in the original STROBE checklist.

Reference

1. Orchard O, Meeuwisse W, Derman W, et al. Refinement and presentation of the Calgary Sport Medicine Diagnostic Coding System (SMDSC) and the Orchard Sport Injury & Illness Classification System (OSIICS). *Br J Sports Med* In preparation

APPENDIX H: TURN-IT-IN REPORT

R Solomons Full Thesis

ORIGINALITY REPORT

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