THE DIFFERENCES IN OBJECTIVE BALANCE OUTCOMES BETWEEN ELITE FEMALE RUGBY PLAYERS WITH AND WITHOUT A HISTORY OF LATERAL ANKLE SPRAIN

by

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DECLARATION

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ABSTRACT

Background

Ankle injuries (in particular ankle sprains) are among the most common musculoskeletal injuries in rugby due to impact. Despite the high physicality of the sport, it has not deterred females from participation. Ankle sprains can be prevented or reduced by a balance training programme. Dynamic balance can be quantified by pressure or force platform systems in balance assessments by measuring displacements of the centre of pressure (COP). Despite the popularity of women's rugby, studies in this area are scarce.

Objective

The objective of the study was to determine if there are differences in objective balance outcome measures between female rugby players with and without a history of lateral ankle sprains, using COP displacements to quantify their dynamic balance.

Methodology

A cross-sectional analytical design was followed in this study. The study was conducted at the High Performance Centre Gymnasium of the Western Province Rugby Football Union (WPRFU), situated at the corner of Voortrekker Road and Duminy Street, Bellville, Cape Town. The study involved 12 participants with a history of lateral ankle sprains and 19 participants without a history of lateral ankle sprains. The Noraxon myoPressure™ (Zebris) pressure plate was utilised to objectively measure dynamic balance using COP parameters, namely Sway Area (SA), COP Speed (COP Sp), and Time-to-Boundary (TTB), using three tasks (*catch-and-throw*, *single-leg balance*, and *side step*). The Mann-Whitney statistical test was used to assess normality of the data.

Results

The study population comprised 31 females, 12 with a history of lateral ankle sprains and 19 without a history of lateral ankle sprains. The median age of the ankle sprain group was 21.5 years, similar to the non-ankle sprain group of 21.0 years. Participants of the ankle sprain group presented with statistically significant differences in the outcome Sway Area for the tasks *catch-and-throw* (p=0.04) and *side step* (p=0.01). This was similar for the outcome

Time-to-Boundary which indicated a statistically significant result for the tasks *catch-and-throw* (p=0.02) and *side step* (0=0.01). There was also a statistically significant difference for the outcome COP Speed for the task *side step* (p=0.01). There were no statistical differences for the task *single-leg balance*.

Conclusion

Our findings showed a significant increase in SA and TTB in the ankle sprain group compared to the non-ankle sprain group for the tasks *catch-and-throw* and *side step*. There was also a significant increase in COP Sp in the ankle sprain group compared to the non-ankle sprain group. All other outcomes showed insignificant differences. Our findings add to the evidence base, suggesting that balance can be tested and measured objectively in female rugby players with lateral ankle sprains as a result of balance impairments. In addition, the use of pressure plates in objective balance testing to provide significant data is strengthened and may assist clinicians to identify players whose balance may be impaired following an ankle sprain and who may benefit from a balance training programme. Future studies may explore the effect of a balance intervention programme in female rugby players with and without a history of ankle sprains.

Keywords

Balance, static balance, postural control, dynamic balance, centre of pressure, rugby, ankle sprain

OPSOMMING

Agtergrond

Enkelbeserings (in die besonder enkelverstuitings) is een van die mees algemene muskuloskeletale beserings in rugby as gevolg van impak. Die intense fisieke aard van die sport verhinder egter nie die deelname van vrouens nie. Enkelverstuitings kan voorkom of verminder word deur middel van ‘n balans-opleidingsprogram. Dinamiese balans kan gekwantifiseer word deur middel van druk of krag platform stelsels wat gebruik word vir balans evaluering waar verplasings van die drukmiddelpunt (COP) gemeet word. Ten spyte van die gewildheid van vrouerugby is studies in hierdie studieveld steeds skaars.

Doelwit

Die doelwit van die studie was om met behulp van COP verplasings te bepaal of daar verskille is in die resultate van objektiewe balansmeting in vroulike rugbyspelers met en sonder 'n geskiedenis van laterale enkelverstuitings om die spelers se dinamiese balans te kwantifiseer.

Metodiek

‘n Deursnit ontledingsontwerp is gevolg in hierdie studie. Die studie is uitgevoer by die High Performance Centre Gimnasium van die Westelike Provinsie Rugbyvoetbalunie (WPRFU), geleë op die hoek van Voortrekkerweg en Duminy Street, Bellville, Kaapstad. Die studie het 12 deelnemers ingesluit met ‘n geskiedenis van laterale enkelverstuitings en 19 deelnemers sonder 'n geskiedenis van laterale enkelverstuitings. Die Noraxon myoPressure™ (Zebris) drukplaat is gebruik om dinamiese balans objektief te meet met behulp van COP parameters, naamlik liggaam Swaai Area (SA), COP Spoed (COP Sp), en Tyd-tot-Grens (TTB), deur die uitvoering van drie take (*vang-en-gooi*, *eenbeen balans* en *systap*). Die Mann-Whitney statistiese toets is gebruik om die normaliteit van die data te evalueer.

Resultate

Die studiepopulasie het bestaan uit 31 vroue, waarvan 12 ‘n geskiedenis van laterale enkelverstuitings gespesifiseer het terwyl die ander 19 aangedui het dat hulle nie ‘n geskiedenis van laterale enkelverstuitings het nie. Die gemiddelde ouderdom van die enkelverstuitingsgroep was 21.5 jaar, wat ooreenstem met die nie-enkel verstuitingsgroep van 21.0 jaar. Deelnemers van die enkelverstuitingsgroep het statisties beduidende verskille getoon in die Swaai Area uitkoms vir die *vang-en-gooi* (p=0.04) en *systap* (p=0.01) take. Die TTB het 'n soortgelyke statisties beduidende resultaat getoon vir die *vang-en-gooi* (p=0.02) en *systap* (0= 0.01) take. Daar was ook 'n statisties beduidende verskil in die COP spoed uitkoms vir die *systap* (p=0.01) taak. Daar was geen statistiese verskille vir die *eenbeen balans* taak nie.

Gevolgtrekking

Ons bevindinge het getoon dat daar 'n beduidende toename is in die liggaam SA en TTB parameters by die enkelverstuitingsgroep in vergelyking met die nie-enkelverstuitingsgroep vir die *vang-en-gooi* en *systap* take. Daar was ook 'n beduidende toename in COP spoed by die enkelverstuitingsgroep in vergelyking met die nie-enkelverstuitingsgroep. Alle ander resultate dui onbeduidende verskille aan. Ons bevindinge dra by tot die fundamentele bewyse dat balans objektief getoets en gemeet kan word in vroulike rugbyspelers met laterale enkelverstuitings as gevolg van balans gestremdhede. Die gebruik van drukplate met objektiewe balanstoetse om beduidende resultate te lewer word verhoog en kan klinici help om spelers te identifiseer wat gestrem is as gevolg van 'n enkelverstuiting en wat bevoordeel kan word deur 'n balans opleidingsprogram. Toekomstige studies kan die effek van 'n balans intervensieprogram in vroulike rugbyspelers met en sonder 'n geskiedenis van enkelverstuitings ondersoek.

Sleutelwoorde

Balans, statiese balans, postuurbeheer, dinamiese balans, drukmiddelpunt, rugby, enkelverstuiting

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I dedicate this thesis in loving memory of Joseph J Markgraaff, a close friend who passed away before I completed this journey.

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ABBREVIATIONS

Abbreviation	Full Word / Term
AS	Ankle Sprain
BESS	Balance Error Scoring System
BOS	Base of Support
BMI	Body Mass Index
COP	Centre of Pressure
COP Sp	Centre of Pressure Speed
mBESS	Modified Balance Error Scoring System
NAS	Non-Ankle Sprain
SARU	South African Rugby Union
SA	Sway Area
SEBT	Star Excursion Balance Test
TTB	Time-to-Boundary
WPRFU	Western Province Rugby Football Union

GLOSSARY

Word / Term	Definition
Acute lateral ankle sprains	Traumatic injury to the lateral capsular ligament of the ankle, which is diagnosed within 72 hours after occurrence (Kerkhoffs et al., 2012). Sudden onset injuries, occurring in a time frame of zero to four days after trauma event (Knight, 2008).
Ankle sprain	For the purpose of this study, ankle sprain injury will be defined as trauma that disrupted the structures of the ankle, which occurred during a practice or competition session (Trojian & McKeag, 2006).
Anterior Drawer Test	A test used to determine ligament laxity or instability in the ankle by testing primarily the anterior talofibular ligament in the ankle (Van Dijk et al., 1999; Jaffer Aradi et al., 1988).
Balance	A generic term describing the dynamics of body posture to prevent falling. It is the ability of the body to maintain the COG within the limits of stability as determined by the base of support (Palmieri et al., 2002).
Centre of pressure (COP)	The point where the total sum of a pressure field acts on a body, causing a force to act through that point (www.wikipedia.org).
Chronic ankle sprains	Acute injuries which may occur multiples times. Reoccurrence of the injury may be because of inadequate rehabilitation before commencing activities (Knight, 2008).
Concussion	A brain injury caused by trauma that transmits force to the brain either directly or indirectly and results in impairment of brain function (www.boksmart.sarugby.co.za).
Dynamic balance	The ability to perform a task while maintaining a stable position (Ricotti, 2011).
Elite	Rugby played between representative teams of unions, cross-border rugby played between senior clubs, provinces, states and other sub-unions or associations of unions and such other rugby within its territory as a union may decide is elite rugby; and elite adult rugby shall be elite rugby played by teams comprising players normally 18 years of age and older (www.sarugby.co.za).
Functional rehabilitation	Consists of a treatment plan for ankle sprains of PRICE (Protection, Rest, Ice, Compression, Elevation), early range of motion, strengthening, proprioceptive exercises and functional exercises (Osborne & Rizzo, 2003).

Word / Term	Definition
Lateral ankle sprains	Occurs when the ankle is in a position of less stability (plantar flexion, inversion); the lateral ankle ligament is more likely to be injured. The lateral ankle ligament is composed of the anterior talofibular ligament, calcaneofibular ligament and the posterior talofibular ligament (Anderson, 2002).
Mechanoreceptors	Sensory receptors found in the lateral ankle ligament and joint capsule, which are able to detect a change in joint position (McKeon & Hertel, 2008).
Posturography	Objectively utilises the displacement of COP data to quantify postural sway by means of sensors embedded in the force platform system (Schubert & Kirchner, 2014).
Postural sway	Refers to the changes in the COG (Palmieri et al., 2002).
Proprioception	The lateral ankle ligament and joint capsule contain mechanoreceptors. Proprioception is the ability of these sensory receptors to detect change in a joints position. When there is ligament damage, there is a disruption of these sensory receptors to detect changes in joint position, resulting in altered proprioception (Hertel, 2000).
Static balance	The ability to maintain a base of support with minimal movement (Ricotti, 2011).
Sub-acute ankle sprains	Timeframe for injuries are generally five to fourteen days following trauma event (Knight, 2008).
Vestibular	Described as the sensory mechanism in the inner ear that detects movement of the head and helps to control balance (www.collinsdictionary.com).

CHAPTER 1: INTRODUCTION

Rugby is one of the most popular sports in the world and players are exposed to a high risk of injury (Mathewson & Grobbelaar, 2015; Brooks & Kemp, 2008). A systematic review by Fong et al. (2007) identified the ankle (12%) as the third most common injured area in rugby, preceded by the head (14%) and thigh (13%). Ankle sprains in particular were identified as the most common type of ankle injury (75%), involving the rupture or tear of the anterior talofibular ligament. However, despite the high physicality and contact nature of the sport, it has not deterred females from participation (King et al., 2019).

Ankle sprains most commonly occur in rugby due to impact or collision of players (Richie & Izadi, 2015; Brooks & Kemp, 2008) when the ankle usually twists inward. The tackle is considered the most dangerous phase of play as it contributes 61% of all injuries in rugby, with joint sprains more common to the ball carrier (Mathewson & Grobbelaar, 2015). However, ankle sprains may also occur spontaneously in rugby during running, cutting and uneven field surfaces. From a South African context, the prevalence of ankle sprains is unknown in both men and women rugby sport codes (Simpson et al., 2014; Parker & Jelsma, 2010). Ankle sprains can be prevented or reduced by a balance training programme (Han et al., 2015; Schifton et al., 2015). Technological advancements in balance assessment over time have led to the utilisation of pressure or force platform systems to quantify dynamic balance (Schubert & Kirchner, 2014; Mancini & Horak, 2010; Duarte & Freitas, 2010). These systems can objectively assess postural sway by detecting displacements of the centre of pressure (COP) by means of sensors embedded in the platform structures (Ricotti, 2011).

Despite the worldwide growing trend in the popularity of women's rugby, it is still an under-researched area, as most studies in rugby are conducted on their male counterparts. The purpose of this study was therefore to determine if there are differences in objective balance outcome measures between female rugby players with and without a history of lateral ankle sprains, using COP displacements to quantify their dynamic balance. Results from this study could provide a baseline for future objective quantitative testing and analysis.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Rugby union, commonly referred to as rugby, is a contact sport that can result in a high risk of injuries. The South African Rugby Union (SARU) is the governing body of rugby with over 430,000 registered players, making it one of the most popular team sports in South Africa. Rugby played an important part in South Africa's post-apartheid era when the country hosted and won the 1995 Rugby World Cup and won again in 2007 when it was hosted in France. Currently the male national team (commonly referred to as Springboks) are the 2019 World Rugby Champions and is considered the best performing rugby team in the world. Considering that rugby is a high contact sport, it places players at higher risk of injury during a match compared to any other team sport (Mathewson & Grobbelaar, 2015).

Despite rugby being a challenging and vigorous collision sport, it has not intimidated women from participating (Carson et al., 1999), with an increase in participant growth noted in countries such as New Zealand, Australia, Canada, Great Britain, South Africa and the United States of America (King et al., 2019). In South Africa, the Springbok women team has recently qualified for the 2021 Women's Rugby World Cup to be held in New Zealand, further adding to the popularity of rugby as a sport. According to an HSBC (2016) report, "The Future of Rugby", women's rugby is currently the fastest growing team sport in the world. The aim of the World Rugby 2017-2025 Development Plan for women is to have rugby as the global leader in sport where women involved in rugby will have equity on and off the field. The international regulatory body also revealed that the number of registered female players worldwide increased by 32% between 2014 and 2015. The increasing participation of women in rugby is accompanied by a rise in the number of injuries (King et al., 2019; Sallis et al., 2001); however, this has not deterred women from participating in rugby.

Studies among female rugby players are scarce and under-researched (King et al., 2019). In contrast to their male counterparts, rugby-related injuries have increased globally and specifically in South Africa (Ras & Puckree, 2014). A systematic review by King et al. (2019) identified concussions and lower limb sprains as the most common injuries sustained during match and training in women's rugby. Differences in biomechanical factors between the sexes are highlighted to place females at a higher risk than males (King et al., 2019). Females reportedly have lower physiological aspects such as reduced speed, agility, muscle power, maximal aerobic power, and a greater relative mass and skinfold thickness, placing them at a higher injury risk. Carson et al. (1998) identified injuries in an elite Canadian female rugby team and compared it to other similar contact sports. According to the results, the incidence of injuries in women's rugby is comparable with other contact sports such as soccer since they are both team sports, which may result in collision of players. Similarly, a descriptive cross-sectional study by Niyonsenga and Phillips (2013) highlighted the high proportion (45%) of injuries sustained by female soccer players in Rwanda. The authors found that both extrinsic and intrinsic factors might have contributed to this high number of injuries. Extrinsic factors related to playing surface, level of competition, level of skill, shoe type and prophylactic use of ankle bracing might have contributed to injuries whereas intrinsic factors such as age, sex, previous injuries, inadequate rehabilitation, limb dominance, postural stability and menstrual cycle to name a few, might also have played a role (Niyonsenga & Phillips, 2013). The study further reported that the majority of injuries were in the lower limb, with the ankle more prone to injury as this was the point of contact. From a South African context, the prevalence of ankle sprains is unknown since ankle sprains are typically under-reported as it is considered a minor injury (Simpson et al., 2014).

The aim of this review is to report the current scientific knowledge on balance impairments resulting from ankle sprain injury amongst female rugby players. The importance and relevance of performing objective balance assessment in sport will also be presented.

2.2 Methodology of literature review

The current literature on key concepts surrounding balance in rugby and lateral ankle sprains was evaluated. A broad literature search was performed using the following electronic databases: Google Scholar, PubMed, and Medline. There were no date restrictions to published literature included from inception until November 2019. The following key search terms were used: balance; static balance; postural control; dynamic balance; centre of pressure; rugby; female; ankle sprain. Studies deemed relevant to the topics covered in this literature review were selected. A search of reference lists and pearling of all retrieved articles was used to identify any additional publications with similar topics meeting the aim of this review.

Ankle sprains are the most common injury in sport comprising up to 45% of all injuries (Richie & Izadi, 2015). In the Netherlands, just over half a million ankle sprains are reported annually (Simpson et al., 2014). The prevalence of ankle sprains in South Africa is unknown because it is considered a minor injury and frequently under-reported (Simpson et al., 2014). The mechanism of injury for ankle sprain involves stretching or tearing one or more ligaments of the ankle, with lateral ankle sprains being more common than medial injuries in sports or recreational activities (Hubbard & Hicks-Little, 2008). It may also involve damage to the surrounding capsule, which causes bleeding in the tissues, resulting in a swollen ankle. In rugby specifically, ankle sprains may occur as a result of running, tackling, cutting or incorrect landing (Faude et al., 2006). When there is ligament damage, as in the case of ankle sprains, it results in altered proprioception (Han et al., 2015), further predisposing the ankle to injury (Schifton et al., 2015). Due to the high rate of ankle sprains and the adverse effects it has on participation levels, the need arose for preventative measures in sport (Hupperets et al., 2009).

2.3 The importance of balance in rugby

Optimal balance is important in rugby for players to avoid falls whilst performing and executing highly skilled tasks (Faude et al., 2006). Specific tasks include tackling, kicking, passing and catching (Chiwaridzo et al., 2016). The control of balance requires a complex interplay between proprioceptive, vestibular, and visual factors (Ras & Puckree, 2014). A disturbance in balance may therefore predispose a player to ankle injury (McGuine & Keene, 2006) due to altered postural responses. This section highlights the importance of balance in rugby and related ankle injuries.

2.3.1 Injury prevention

Rugby is associated with a higher risk of injury and has a high prevalence to the lower limb (King et al., 2019), specifically ankle injuries (Ras & Puckree, 2014). A disturbance in balance may result in altered postural responses, which may lead to ankle injury (Hammami et al., 2014; Ras & Puckree, 2014). Balance disturbances may be avoided with proprioceptive, stability and functional exercises (Schifton et al., 2015). Proprioceptive exercises challenge the ability of the targeted joint to detect and react to afferent input regarding joint position. Examples are *single-leg balance* on a balance pad, balancing on a wobble board, and balancing with eyes closed. Rugby-specific proprioception exercises may include *single-leg balance* whilst catching and throwing a ball or *jump landing* from a height. A systematic review and meta-analysis by Schifton et al. (2015) favours proprioceptive training as an effective intervention in reducing the incidence and occurrence of ankle sprains in sporting populations. Fong et al. (2007) conducted a systematic review recommending that ankle sprain prevention exercises be implemented in rugby particularly, since the incidences were highest in team sports. The benefits include preventing the reoccurrence of ankle injuries in athletes up to 12 months post-injury (Kerkhoffs et al., 2012), and improving static and dynamic balance. Proprioceptive balance training is utilised in rehabilitation following sport-related injuries and is becoming recognised as an important element in injury prevention in sports (Emery et al., 2005). A balance training programme implemented pre-season and maintained throughout the season will reduce the risk of ankle sprains, enhancing ankle sprain prevention measures (McGuine & Keene, 2006). This in turn will enhance balance and encourage a better execution of sport-related tasks.

2.3.2 Execution of highly skilled rugby-specific tasks

The complexity of rugby as a sport requires players to execute highly skilled tasks such as sprinting, changing direction, passing the ball to team members, and taking contact whilst maintaining their balance (Faude et al., 2006). Players are also required to maintain balance with directional changes in running and tackles as well as being able to analyse the game, think ahead, and predict what will happen from set attacking and defensive plays (Hammami et al., 2014). The combination of high physical demands alongside exposure to collisions and contact means the inherent risk of injury whilst playing rugby is substantial (Williams et al., 2013). Hammami et al. (2014) further explain that players need to process information very quickly in combination with their skilled tasks in order to maintain their balance optimally. In addition to this, it is vital that the three proprioception, vision, and vestibular afferent systems provide the necessary information for its performance.

2.3.3 Contact and tackling

Rugby is characterised by short intermittent bouts of high intensity activity and multiple high-impact contact situations (Kraak et al., 2019). The majority of injuries at senior elite levels result from contact phases during match play, which carries inherent risks towards players (Kraak et al., 2019). Players are expected to maintain postural control whilst being tackled or whilst avoiding tackles by opponents (Hammami et al., 2014). To maintain a state of balance or equilibrium during contact, players are expected to integrate both internal (proprioception and vestibular systems) and external (visual) cues efficiently (Hammami et al., 2014). This requires players to lower their centre of gravity, which requires a body reorientation strategy that could decrease their balance potential (Hammami et al., 2014).

Successful body orientation/reorientation strategies are essential during contact phases of rugby for successful balance performance.

2.3.4 Sport performance enhancement

Performance in rugby is attributed to various factors such as endurance, muscular strength, power, speed, agility, and flexibility (Chiwaridzo et al., 2016; Williams et al., 2013). Lack of these physical attributes may have a negative impact on player performance efficiency. Postural control or balance enables players to move more efficiently, thereby enhancing these attributes. A systematic review conducted by Troester et al. (2018) indicates that the *single-leg balance* and *landing* tasks are associated with performance and injury occurrence. Conditioning programmes for rugby players tend to focus on strength and cardiovascular training; however, performance and rugby skills may be enhanced through balance training programmes as it has been proven to lessen the risk of injury (Sefton et al., 2011). A systematic review by McKeon and Hertel (2008) encourages the use of a balance training programme as a preventative measure to effectively decrease the incidence of initial ankle sprain or as a treatment to reduce recurrent ankle sprains. A correlation may therefore be seen between performance and balance, which is fundamental to the execution of tasks.

2.4 Factors that may influence balance in rugby players

Various factors have been suggested in literature to have an impact on balance. This section presents the most applicable factors related to rugby.

2.4.1 Ankle injury

The lack of ankle joint stability has a negative effect on proprioception, and balance as a disturbance in stability can affect unilateral standing negatively (Akbari et al., 2006). In a systematic review conducted, McKeon and Hertel (2008) report that ankle injuries may lead to associated damage to mechanoreceptors in ligaments, thereby reinforcing the fact that poor balance ability is associated with increased risk of injury. Randomised control trials conducted by Emery et al. (2007) as well as McGuine and Keene (2006) encourage proprioceptive balance training to reduce the risk of sport-related ankle sprains significantly and may be utilised in rehabilitation as an effective means of improving static and dynamic balance. In women’s rugby, a systematic review identified the ankle as the most common region, in particular a sprain (King et al., 2019).

2.4.2 Gender

Women athletes stand a 25% increased risk of sustaining an ankle sprain (Kofotolis & Kellis, 2007). A prospective cohort study conducted on ankle sprain in female basketball players highlights that risk factors making women more susceptible include the age of the player, whether the player has been injured at training or during a game, mechanism of injury, body size as well as a previous history of injury. Although age of the player is debatable, the study addresses the incidence of injury, which indicates that exposure to injury over time in older players is greater than in younger players. Possible reasons include that players with more training experience have a longer history of exposure to injury, which may demonstrate a higher injury rate. Another possible increased risk of injury in females may be attributed to limb dominance. Faude et al. (2006) and Willems et al. (2005) explored the association between limb dominance and ankle sprains in female soccer players, citing that the preferred leg for landing, kicking and pushing off with is more at risk. It is debatable whether biomechanical differences between the sexes may increase the risk of injury in women. Factors such as lower muscle power, less agility and reduced speed are hypothesised to place women at a higher risk in comparison to men (King et al., 2019). However, King et al. (2019) argue that in terms of sport participation, women may have similar attitudes to men in areas such as aggression and physicality. The difference in injury incidence can therefore be attributed instead to the increase in popularity of women's rugby.

However, since published data in women's rugby are scarce in comparison with men's rugby, further research is strongly recommended.

2.4.3 Neuromuscular control

Mechanical and sensorimotor insufficiencies caused by injury may lead to impaired postural stability and altered movement patterns in functional activities (O'Driscoll & Delahunt, 2011). Deficits in postural control may occur because of damage not only to the ligaments but also to the mechanoreceptors in the ligaments, joint capsule, and retinacula around the ankle joint, which provides afferent information to the central nervous system about joint movement and position (Richie & Izadi, 2015). This information is vital for maintaining balance or postural control during activities. Loss of postural control following an ankle sprain results in loss of proprioception, nerve conduction, strength deficits and reduced range of motion, controlled by a feed forward or efferent side of neuromuscular control of the ankle (Richie & Izadi, 2015). A systematic review by Zech et al. (2010) concluded that balance training could be effective for postural and neuromuscular control improvements. Restoring neuromuscular control may incorporate an effective rehabilitation programme, which focuses on all aspects as unrehabilitated ankles may lead to long-term deterioration of balance (Richie & Izadi, 2015). Although peroneal muscle strength has been the focus of both causing and resulting from an ankle sprain, patients with functional ankle instability tend to display weakness of inversion muscle strength and plantar flexors, and rehabilitations programs now emphasise eccentric and concentric exercises of all muscle groups (Richie & Izadi, 2015).

2.4.4 Body Mass Index (BMI)

BMI is a screening tool that represents an index of an individual's weight (Swarnalatha et al., 2018). It is calculated as weight (in kilograms)/height (in meters, squared). BMI is typically divided into four categories, namely underweight, normal, overweight, and obese. In a non-experimental observational study, Swarnalatha et al. (2018) evaluated the correlation between BMI and dynamic balance, using the Star Excursion Balance Test (SEBT). SEBT is a dynamic test that requires strength, flexibility, and proprioception, and is effective in measuring dynamic postural control. A *single-leg* stance is maintained in the centre of a star pattern whilst the participants' possible reach distance is measured in multiple directions with the non-stance limb (Swarnalatha et al, 2018). The study concluded that BMI has no influence over dynamic balance. However, a cohort study by McHugh et al. (2007) found an increased risk of an inversion ankle sprain associated with a high body mass index. Players were categorised as minimal, low, moderate, and high risk based on previous ankle sprain history and BMI. Players in the low-, moderate-, and high-risk group were placed on a balance intervention on a foam stability pad. Post-intervention injury incidence was compared with pre-intervention. The incidence of injury was 19 times higher in football players who had a history of a previous ankle sprain and who were overweight compared with players who had no previous ankle sprain and who were of normal weight. A cross-sectional survey by Koenig and Puckree (2015) also found that a higher BMI could negatively influence balance and result in falls, since significant correlations were found between BMI and static balance, measured by Sway Index. Evidence is in support of the study of McHugh et al. (2007), as the level of evidence is higher (level 2).

2.4.5 Player position

A systematic review by King et al. (2019) provided inconclusive results on player position affecting injury in rugby players. Positional roles (forwards and backs) varied according to level of participation. Backline players were more affected in the community, whereas forwards were more affected at elite level, with the prop and centre position the most common position injured. The majority of injuries at senior elite levels result from contact phases during match play (Kraak et al., 2019), which may be a contributing factor to forwards being more susceptible to injury than backs.

2.4.6 Lower extremity injuries

Women are considered to be at higher risk of sustaining injury to the anterior cruciate ligament (Sallis et al., 2000). A retrospective study comparing injury patterns between men and women over sporting codes indicated that females displayed a higher rate of anterior cruciate injuries than their male counterparts. Underlying knee muscle weakness and reduced stability due to previous injury may also contribute to a disturbance in balance.

2.5 The implications of balance-related impairments

Postural control deficits have been linked with an increased risk of acute ankle sprains (Chander et al., 2014), which in turn has an effect on cost and performance in sport. The purpose of this section is to explore the implications of postural control impairments as related to sport-related ankle sprains.

2.5.1 Musculoskeletal injury

Chronic ankle instability may develop because of repeated sprains, persistent weakness, laxity of ligaments, and joint degenerative changes (Richie & Izadi, 2015). Between 19% and 72% of people who develop ankle sprains may develop a recurrent episode of another sprain in the future (Richie & Izadi, 2015). Ankle joint instability over time results in damage to the articular surfaces within that joint, which increases the risk of developing osteoarthritis (Brown & Mynark, 2007). Instability may be prevented through an effective rehabilitation programme involving balance and proprioceptive exercises (Schifton et al., 2015; Richie & Izadi, 2015).

2.5.2 Participation and performance in sport

2.5.2.1 Time loss

Ankle sprains may result in numerous visits to emergency care facilities and significant loss of time from sports participation (McGuine & Keene, 2006). Lateral ankle sprains are usually graded on the basis of severity (Petersen et al., 2013). Grade I is a mild stretching of the lateral ligaments without rupture or joint instability. Grade II is a partial rupture of the anterior talofibular ligament with pain and swelling resulting in functional limitations, and grade III is a complete rupture of the anterior talofibular ligament with marked pain, swelling and impairment of function with instability (Petersen et al., 2013). Ligament healing can be divided into the inflammatory phase (until ten days after trauma), the proliferation phase (four to eight weeks after trauma), and the remodelling phase (until one year after trauma). A systematic review performed by Hubbard and Hicks-Little (2008) to determine the healing time of the lateral ankle ligaments after an acute ankle sprain suggests that an exact timeline of ligament healing cannot be provided based on the articles reviewed; however, researchers report that improvement in mechanical stability were not seen until six weeks to three months after trauma, indicating that players may be returning to activity before the ankle is healed fully (Hubbard & Hicks-Little, 2008).

Functional rehabilitation of ankle sprains, in comparison with immobilisation, is associated with an earlier return to work or sport and reduced economic costs (Simpson et al., 2014). This also results in less time off from training and earlier return to participation in sport.

2.5.2.2 Cost

Ankle sprains have a profound impact on health care costs and resources (McGuine & Keene, 2006). The cost associated with treating ankle sprains in the USA is staggering. Up to 70% of people sustaining an ankle sprain develop persistent weakness, repeated ankle sprains, pain during activities, and self-reported disability (Richie & Izadi, 2015). In 2003 alone, it is estimated that the direct cost of treating ankle sprains in high school soccer and basketball players were $70 million (McGuine & Keene, 2006). There is also significant public health cost associated with sport injuries, as ankle sprains may result in long-term disability (such as osteoarthritis), which may have a further impact on healthcare costs and resources (Emery et al., 2007). In South Africa, the associated costs are unknown since the prevalence is unknown

(Simpson et al., 2014). Access to tertiary healthcare is limited in developing countries such as South Africa, which poses a huge challenge (Parker & Jelsma, 2010).

2.6 Current understanding of balance

Dynamic balance is essential for performing dynamic tasks in competitive sport, which places various demands such as speed, impact, change of direction and agility on the body (Chander et al., 2014).

2.6.1 Definition of balance

Balance, a generic term commonly describing the dynamics of body posture to prevent falls, is characterised by postural sway (Gerbino et al., 2007). It is defined as the ability to maintain equilibrium when either standing or moving. Good balance (postural control) results in as little sway as possible and poor balance (postural control) results in excessive sway. Balance can be defined as the ability to maintain the centre of gravity within the base of support with minimal sway (Chander et al., 2014). For optimal balance, the body has to integrate information from the sensory (visual, vestibular, and somatosensory) system as well as the motor (joint range of motion and strength) system to be processed in the central nervous system (Hammami et al., 2014; Mancini & Horak, 2010). Changes in both sensory and motor systems can result in a disturbance to these systems and may alter postural responses.

2.6.2 Categories of balance

Balance can be classified into two broad categories, namely static and dynamic balance. Static balance is described as the ability to stand within a base of support with as little postural sway as possible (Ricotti, 2011). Dynamic balance is the ability to perform a task while maintaining a stable position (Ricotti, 2011). Both static and dynamic balance is important for sport players to maintain their balance whilst performing dynamic tasks in sport (Chander et al., 2014).

2.6.3 Balance and sport

Different sports have different balance requirements of the player and therefore assessing both static and dynamic balance helps to analyse the effectiveness and the role of somatosensory (proprioceptive), visual and the vestibular systems along with the neuromuscular efficiency of the players (Chander et al., 2014). Superior balance ability is necessary in sport to achieve the highest competitive level and avoid lower limb injuries (Han et al., 2015). During most sport activities, the ankle-foot complex is the only body part in contact with the ground, suggesting that ankle proprioception may be one of the most important contributing factors to balance control (Han et al., 2015). Improving balance control should therefore be one of the most important goals.

2.6.4 Definition of proprioception

Proprioception is defined as a complex neuromuscular process concerned with the internal kinaesthetic awareness of body position and movement (Schifton et al., 2015). It relies on afferent and efferent signalling and plays an important role in joint stability and injury prevention. Sensory receptors (mechanoreceptors) found in the lateral ankle ligament and joint capsule are able to detect change in a joints position and with ligament damage, like ankle sprains, it results in altered proprioception, thereby causing a disturbance in balance (Han et al., 2015).

2.6.5 The influence of proprioception on balance

Ankle proprioception is critical for balance control (Han et al., 2015). It provides information to enable adjustments of the ankle position and movements of the upper body in order to perform complex motor tasks successfully (Han et al., 2015). However, research is inconclusive with respect to the effectiveness of proprioceptive training in athletes without any history of an ankle injury. Injured ligaments in an ankle sprain cause damage to the sensory receptors at the ankle joint and thereby diminish postural control (Han et al., 2015). Ankle injuries can be prevented with proprioceptive balance training. In a prospective randomised controlled trial, Eils et al. (2010) evaluated the effectiveness of proprioceptive balance training as well as the effects on neuromuscular performance. The results of this study indicate that proprioceptive training was effective in the prevention of recurrent ankle injuries. Proprioceptive training programmes are considered effective in reducing the rate of ankle sprains in sport participants (Schifton et al., 2015), thereby improving balance and sport performance.

2.7 Measurement of balance in sport

Several tests have been developed over past decades to measure balance. Traditionally, static balance testing consisted of measuring the length of time a subject can maintain a posture of equilibrium (Ricotti, 2011). However, due to the advancement in technology, the measurement of balance has evolved. Currently, a force platform is the "gold standard" used to measure balance (Alonso et al., 2014; Jones et al., 2011). This section will briefly explore past techniques used, with the focus primarily on current concepts in literature to assess balance in sport, specifically in rugby.

In the past, the Romberg Test was used to assess static balance on the field (Zemková, 2011). In a review article, Zemková (2011) describes the test requiring a player to stand erect, with the feet placed alongside each other, arms alongside the body, and eyes closed. A tendency to sway or lose postural control is considered an indication of loss of proprioception (Ricotti, 2011). Dynamic balance on-field testing required the player to either stand with both feet or on one foot on a foam mat or unstable surface for a certain amount of time (Zemková, 2011). These tests have been criticised for their lack of sensitivity and objectivity and their inability to quantify balance comprehensively, as it is more a measure of the time a player can maintain a particular posture.

Balance tests utilised in rugby include the Star Excursion Balance Test (SEBT) and the modified Balance Error Scoring System (mBESS). In a descriptive study, Coughlan et al. (2014) evaluated a group of elite junior male rugby players using the SEBT, a validated and reliable method to predict lower extremity injury (Gribble et al., 2012; Plisky et al., 2006). The favourable findings of this study encourage the test to be used as a measure to compare dynamic postural stability (Coughlan et al., 2014). The mBESS test is widely used in the assessment of sport-related concussion (Ricotti, 2011). In a study on female soccer, basketball and gymnasts, Bressel et al. (2007) conducted a quasi-experiment comparing static balance (three stance tests) and dynamic balance (BESS and SEBT). Results between groups did not differ much, which only reinforces the disadvantage of the tests as a lack of objectivity.

This led to the development of a more sensitive, reproducible and reliable method of balance assessment known as posturography (Mancini & Horak, 2010). The technique, used to measure body sway or an associated variable, is cconsidered the most reliable method of testing balance (Duarte & Freitas, 2010). Posturography objectively utilises the displacement of COP data to quantify postural sway by means of sensors embedded in the force platform system (Schubert & Kirchner, 2014; Mancini & Horak, 2010). Sport facilities have been using equipment to measure body sway quantitatively in different tasks (Duarte & Freitas, 2010), therefore not limiting its use only in laboratory settings.

In a systematic review and meta-analysis, Muehlbauer et al. (2015) quantified an association between variables of balance and lower extremity muscle strength. Studies included in this review investigated the displacement of COP data, and concluded that COP data are able to identify at-risk individuals and can be used to customise skills-related exercise programmes. Various studies have used COP parameters to quantifying balance. A cohort study by Steib et al. (2013) utilised COP sway velocity (synonymous with COP Sp) and Time-to-Stabilisation (TTS) (synonymous with TTB) to measure balance. A cohort study by Gerbino et al. (2007) objectively measured COP displacement using Sway Index (synonymous with Sway Area). Recently, Troester et al. (2018) identified sway velocity as very reliable (r=0.32-0.94). TTS reliability ranges from moderate to excellent (ICC=0.40; ICC=0.96). *Single-leg balance* and *jump landing* were considered the most reliable measure of assessing balance on a force plate.

A disadvantage is that force platforms are expensive instruments and require evaluators with experience in the use of the equipment (Alonso et al., 2014). A validation study by Goetschius et al. (2018) correlated laboratory force plates and pressure mat devices and concluded that pressure mats are a viable option for detecting postural changes during short duration testing as they are light, compact and easy to use in a clinical setting.

Sport-specific balance testing has therefore focused on static and dynamic posturography and until recently, task-oriented balance tests were used in the assessment of balance (Zemková, 2011). To my knowledge, no research focusing on balance in women's rugby has been explored. The aim of this study was to utilise current balance testing and combine it with sport-specific tasks in order to compare balance in female rugby players with and without a history of ankle sprains.

2.8 Conclusion: Summary of main findings from the literature review

Balance plays a vital role in rugby, and impairment in balance as a result of ankle sprains may lead to further injury, postural control deficits, and have an effect on a players' sport performance. Therefore, objective balance assessment is needed to prevent ankle sprains through an effective balance training programme.

The next chapter will discuss the methodology followed in this study.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter provides details and motivates the study design and methodological approaches used to answer the research question. The study design, setting, population, procedures, data management, and the pilot study conducted have been included. The ethical considerations observed in this study are also presented in this chapter.

3.2 Study design

This study was conducted using a cross-sectional analytical design. Both the outcome and the exposure of the participants were measured at the same time, making it both cost and time efficient. Measurements were conducted to determine the differences in objective balance outcomes between elite female rugby players with and without a history of lateral ankle sprains.

3.3 Study setting

Data acquisition for this study was conducted at the High Performance Centre Gymnasium of the Western Province Rugby Football Union (WPRFU). This facility is situated at the corner of Voortrekker Road and Duminy Street, Bellville, Cape Town. This is the same facility where the participants ordinarily conduct their pre-season testing and training programmes. The researcher sought and obtained permission from the WPRFU administration to use the facility for data collection and for the involvement of their elite senior women training squad as study participants.

3.4 Study population

The WPRFU has a total number of 198 active senior women's club registered players (Blue Jets RFC; Busy Bee RFC; Tygerberg RFC; UWC RFC) for the 2019 season in the Western Cape Metropole. The elite squad was chosen from these members (based on previous games played for the Union and a limited amount of club nominations) and invited to attend the WPRFU elite female senior squad pre-season testing and training programme. In total, 47 registered club players invited by the Union to attend the training formed the study population. Thirty-one subjects attended training and volunteered for this study – 12 subjects with self-reported unilateral ankle sprains and 19 control subjects without a history of ankle sprains to either limb. Participants were recruited in February 2019 at the commencement of their pre-season training programme.

3.4.1 Inclusion criteria

Participants who satisfied the following criteria were included in this study:

- Elite female rugby players representing WPRFU
- Female rugby players 18 years and older from 1 January 2019
- Female rugby players with and without a history of self-reported lateral ankle sprains in the previous 18 months, as indicated on their questionnaire

3.4.2 Exclusion criteria

Participants were excluded from the study if any of the following symptoms were indicated on their screening form:

- Acute, sub-acute, and chronic lateral ankle sprains in the previous three months, with pain and swelling in the ankle joint on the day of testing – pain and swelling affect input to the brain, resulting in balance impairment
- Experiencing dizziness on the day of testing – vestibular or balance disorders can cause dizziness and vertigo, which may result in participants being unsteady on their feet and at risk of falls
- A concussion in the previous three months, which could affect the vestibular system, causing dizziness and balance problems
- Ankle joint fractures where pain and swelling are present in the joint
- Numbness or tingling in the feet as altered sensation could indicate peripheral neuropathy (nerve damage)

3.4.3 Sample size and power calculation

The sample size for this study was determined using a double population proportion formula by considering the following statistical assumptions: 95% confidence interval (CI), power of 80%, allocation ratio 1:1, mean (standard deviation) of 0.73 (0.12) and 0.85 (0.17) for those with and without ankle sprains, respectively. The required total sample size for this study was 50. As the total size of the target population was limited (between 30 and 40 from previous experiences), we applied a finite population correction formula and the minimal sample size needed for a statistical significant result for this study became 24. However, all the players who attended the pre-season training were included in this study. Total population sample was used.

3.5 Recruitment and sampling method

All the senior women players registered at rugby clubs within the WPRFU and invited by the Union to participate in their pre-season training programme were eligible. Participants volunteered to participate in this study and those who met the inclusion and exclusion criteria were recruited for the purpose of this study.

3.6 Data collection

3.6.1 Tool/Instrumentation

Data collection in this study was measured using a 48x40 sense Noraxon myoPressure™ (Zebris) pressure plate from Noraxon USA Inc., which was connected to a laptop loaded with the relevant software (MyoResearch 3.12.17) to automatically calculate COP parameters and pressure distributions. COP parameters can be measured with a force or pressure system. The force system is a technical apparatus that assesses changes in postural sway by recording ground reaction forces projected from the body whilst the pressure system have sensory elements and use the distribution of the force across the sensor grid to calculate COP (Goetschius et al., 2018). In comparison with force plates, pressure plates have the advantage of being low profile, portable, slim, light and easy to transport, making it a popular choice in clinical application to calculate COP data (Goetschius et al., 2018) and hence the reason why it was deemed appropriate for this study.

Literature has shown that pressure plates are reliable devices for COP measurement of static balance (Brenton-Rule et al., 2012). Intraclass correlation coefficients (ICCs) with 95% confidence intervals (CIs) were calculated to determine between-session reliability. The system displayed good to excellent reliability as indicated by ICC values ranging from 0.84 to 0.92. Measurement error as assessed through calculating the standard error of measurement (SEM) and the smallest real difference (SRD) ranged from 1.27mm to 2.35mm (SEM) and 3.08mm to 5.71mm (SRD). The 95% CI ranged from 0.63 to 0.97. The validity of a pressure mat for the use of COP balance measurements was established in this study, and pressure plates were recognised as dependable and valid instruments to determine adjustments in postural sway whilst maintaining balance on one leg. Video cameras were connected to the laptop, capturing the tasks anteriorly and laterally.

Figure 3.1: Noraxon MyoPressure plate

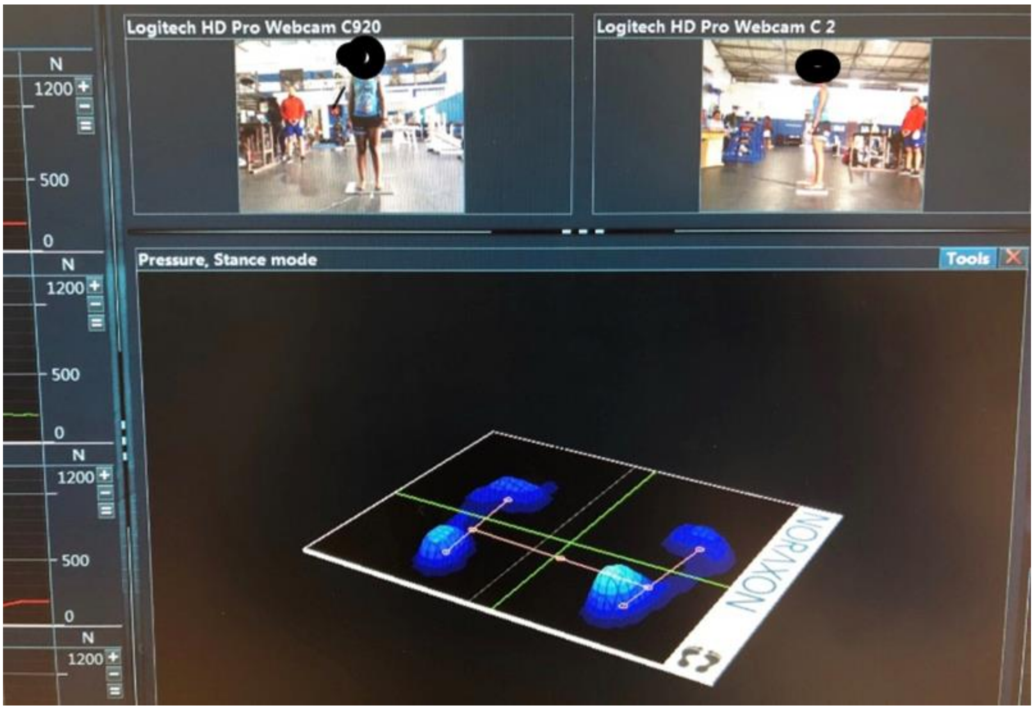

Figure 3.2: Laptop images when Noraxon MyoPressure plate is connected

Figure 3.3: Setup of the Noraxon pressure plate

(Permission has been granted by models in the photographs)

3.6.2 Outcome measures

Currently, the most consistent way to quantify standing balance is by using COP data derived from a pressure or force system (Chander et al., 2014). COP represents the weighted average of all pressures created from the area in contact with the supporting surface (Palmieri et al., 2002). It is a centre point of the distribution of the total force applied to the supporting surface and the most frequent dependent variable used in research in the assessment of balance (Palmieri et al., 2002), and therefore the focus of this study. All COP variables were highly correlated ($r > 92$, $P < .001$), percentage change in COP variables were highly correlated ($r > .85$, $P < .001$), and Cohen’s d effect sizes were all large ($d > 2.25$) between devices (Goetschius et al., 2018).

This study aimed to objectively measuring balance using the COP parameters named Sway Index (SI), Dynamic Postural Stability Index (DPSI), and Time-to-Boundary (TTB). However, since a pressure system and not a force system was used to determine COP parameters, the aforementioned balance outcomes were adjusted and synonymous equivalent parameters were used instead, as the pressure plate does not provide all values needed for algorithms. Sway Area (for Sway Index), COP Speed (for Dynamic Postural Stability Index), and Time-to-Boundary were the outcome measures used instead and will be discussed. These parameters were derived from COP data measured while subjects performed three tasks on the pressure system – *single-leg catch-and-throw*, *single-leg jump landing*, and *side step*.

3.6.2.1 Sway Area

Sway Area (SA), synonymously used with Sway Index in literature, is the area that the COP circumscribes over a discreet period of time (Gerbino et al., 2007). The unit of measurement is mm^2. SA is a 95% confidence ellipsoid equivalent to one standard deviation from the mean COP and reflects the extent or area that data are distributed from the subject's COP (Gerbino et al., 2007; Schubert & Kirchner, 2014). For the purpose of this study, a minimum constant time per subject for each movement was used and SA was calculated by using the subject's COP data and applying a Matlab code integrated with the analyst's software code to determine an actual value.

SA measures a subject's ability to stand still (Gerbino et al., 2007), and can be used to measure static balance after a jump. Since SA has an indirect relationship to static balance, high sway scores typically indicate relatively poor balance (Ras & Puckree, 2014) and may also serve as a predictor of ankle sprain susceptibility (Hrysomallis et al., 2006) (see Figure 3.4).

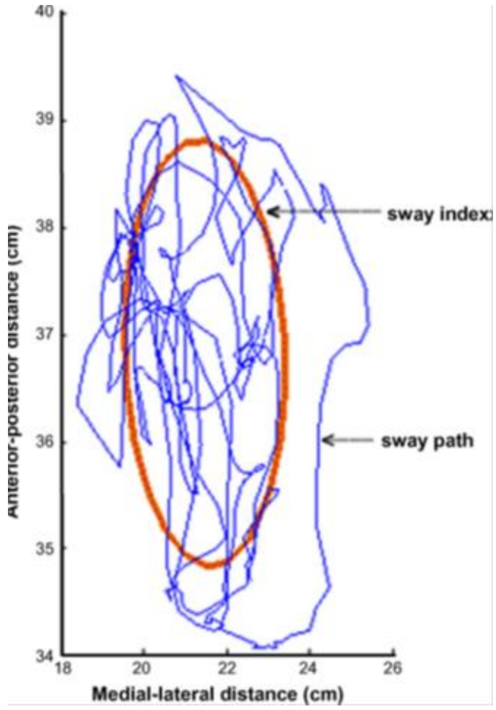

Figure 3.4: Plot of a typical COP map over 10 seconds – the irregular line is the actual sway path. The ellipse is the Sway Area (SA); it reflects the extent that the data are distributed from the subject's COP, indicated by the oval shape (Gerbino et al., 2007)

3.6.2.2 COP Speed

COP Speed (COP Sp) was used as a replacement variable similar to DPSI, as some values needed to calculate DPSI using a mathematical algorithm could not be attained from the pressure plate data (i.e. force vectors in the horizontal direction). COP Sp represents the total distance travelled by the COP over time and can be seen as the time-normalised version of the COP excursion (speed=distance/time). This parameter is determined by dividing total excursion (total distance travelled by the COP over the time duration) by the trial duration and the measurement unit is mm/s. Time calculation (total time used) represented the same as per Sway Area; a constant minimum time across all subjects per movement was used.

An increase in COP velocity is thought to represent a decreased ability to control posture (Palmieri et al., 2002). It can be used as a valuable tool with an athlete's pre-season assessment, as well as a comparison before and after injury, thereby indicating when an athlete may be ready to return to sport (Palmieri et al., 2002).

3.6.2.3 Time-to-Boundary

TTB, synonymously used with Time-to-Stabilisation (TTS), is used to evaluate postural stability as the body transitions from a dynamic to a static state (Flanagan et al., 2008; Wikstrom et al., 2004). TTS is a measure of dynamic stability that analyses the anterior-posterior, medial-lateral, and ground reaction forces during the period the subject is recovering from a perturbation and returning to a static stance (Brown & Mynark, 2007). It measures the time taken for the COP to reach the boundary of the base of support if the COP was to continue on its trajectory at its instantaneous velocity (Hertel & Olmsted-Kramer, 2007). During rehabilitation of the ankle, TTB can be used to detect deficits in postural control where an increase in value would reflect an increase in ankle instability and a decrease in value is indicative of postural instability (Wikstrom et al., 2007; McKeon & Hertel, 2008). The unit of measurement is seconds.

To calculate TTB measures, the foot was modelled as a rectangle to allow for separation of the anterior-posterior and medial-lateral components of the COP. TTB was calculated from a series of TTB measures which shows a sequence of peaks and valleys (known as the minimum) with each valley representing a change in direction of the COP (Hertel & Olmsted-Kramer, 2007). The peaks represent points of instability and the valleys represent points of stability. The dependent variables of TTB calculated are the absolute minimum (smallest of the minimum), the mean of the minimum samples, and the standard deviation of the minimum samples in the medial-lateral and anterior-posterior directions (Hertel & Olmsted-Kramer, 2007).

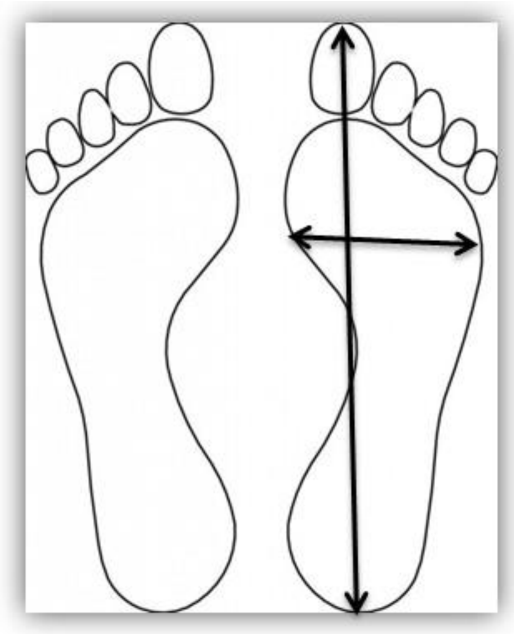

Figure 3.5: TTB is based on COP excursions in the medial-lateral and anterior-posterior directions, using the boundaries of the foot to determine area

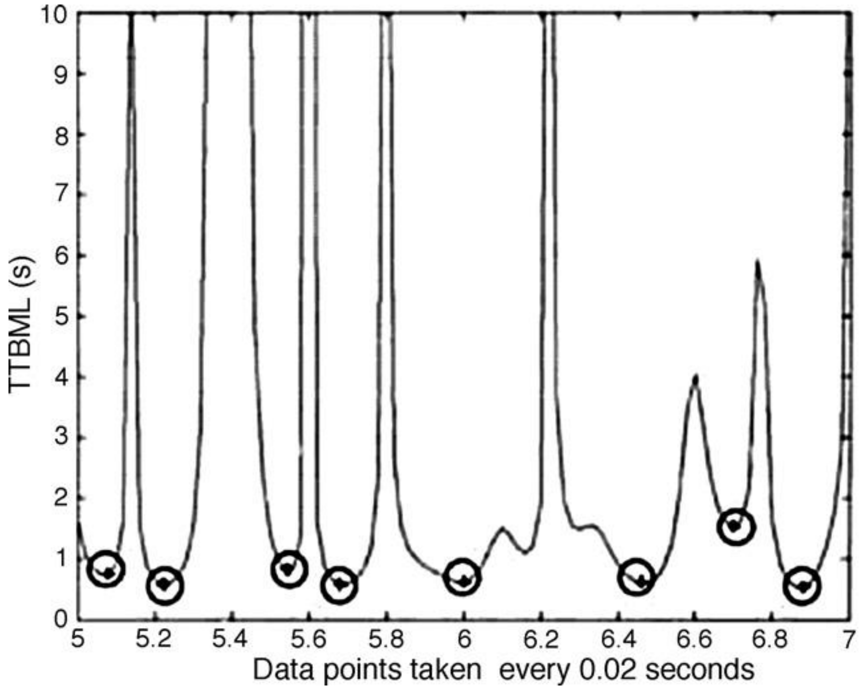

Figure 3.6: Representative medial-lateral Time-to-Boundary (TTBML) data from 2s of a postural control trial. Data were sampled at the minima of the TTBML data stream (represented by circles) (Source: Hertel & Olmsted-Kramer, 2007)

3.7 Study procedures

3.7.1 Informed consent

Data collection commenced in February 2019, at the start of pre-season training for the WPRFU elite senior women. The primary researcher requested players' voluntary participation in this study. Full disclosure about the nature of the study, the aims, requirements, procedures, risks, and benefits involved were explained to the participants. There was no need for translators as all participants could speak English or Afrikaans. Additionally, all potential participants were given ample time and privacy to make their decision. Once the potential participant understood all the information about the study and all the questions had been answered, the informed consent document was signed. Written informed consent (Appendix 1) was obtained from all participants by the primary researcher. It was emphasised to potential participants that the study was voluntary and that they could discontinue their participation at any point without any consequences to themselves by verbalising it to the main researcher. Participants were informed of their right to refuse participation at any point in the study and that it would not involve a penalty or loss of benefits or a reduction in the level of care to which they are entitled. The autonomy of participants was respected throughout this process without the main researcher trying to influence participants' decisions. A study code was assigned to each study participant so that no personal information could be used to identify the participants. The code was a numerical value in the order of testing to each group member. Confidentiality of information was preserved in this way. The team doctor was present for safety concerns and to ensure that consent was freely given and not under duress. The team doctor was available to answer any questions from participants and collect consent forms.

3.7.2 Initial screening

Following informed consent, participants then completed a screening form (Appendix 3), utilised for the screening process of potential participants and for determining their eligibility for this study. Information obtained from the form included the participant's name, age, date of birth and rugby club registration for 2018. Participants also indicated whether they had an ankle sprain or not in the past 18 months. This determined their group allocation, namely with or without a history of ankle sprains. Furthermore, participants had to indicate if they experienced any of a list of symptoms, which either included them or excluded them from this study. If participants were eligible to participate, they completed a questionnaire.

3.7.3 Questionnaire

A questionnaire was completed by all participants. Section 1 consisted of demographic details (weight, height, age). Weight and height were measured by an assistant and the instrumentation used was part of the gymnasium equipment. The questionnaire also included a section on their rugby history and player position. This gave the researcher some insight into the experience of the participant at playing rugby in terms of years as well as whether the player has attained experience at a national level. Section 2 consisted of medical details particularly referring to symptoms on the testing day, to determine if the participant was medically fit and pain free to continue. The WPRFU team doctor was on site with all testing to assist in this regard. Lastly, Section 3 pertained to their ankle sprain history, determining whether the participant had an ankle sprain in the past 18 months or not, and for those who had not, their dominant/preferred side was provided.

Participants who indicated that they had an ankle sprain were assigned to a group that was objectively examined by the primary researcher administering an Anterior Drawer Test to determine ligament laxity or instability in the ankle and compared to the uninjured ankle (Van Dijk et al., 1999; Jaffer Aradi et al., 1988). Participants were lying on their backs with the affected ankle in slight plantar flexion. One hand stabilised the lower leg whilst the other hand grasped the heel. Pressure was applied by the heel in an upward movement and the degree of movement was compared with the uninjured side. It was also noted if this test resulted in any pain for the participant as this would have resulted in their exclusion from the study.

3.7.4 Preparation for testing

Participants were asked to change in the restrooms into their exercise clothes (rugby shorts and tops) for the testing procedure. Shoes were removed as all participants were tested barefoot in order to capture the relevant data. The testing station was pre-set for the data collection process. The Noraxon myoPressure™ mat was connected to a laptop and video cameras were in place anterior and lateral to the position of the mat. The pressure mat was secured to a rubber mat with double-sided tape and the rubber mat was secured to the floor with double-sided tape. This was for the participant’s safety to ensure the pressure mat does not move out of place with contact. Each task was carefully explained and demonstrated by the primary researcher. Stickers with numerical values were used for group allocation and for sequencing of participants’ study identification code.

3.7.5 Instructions to the participants

Participants were individually tested while the rest of the group waited outside the gym area. A practice trial was allowed for participants to familiarise themselves with the task and pressure mat. Both ankles were tested for every participant with each task. For participants of the group without a history of lateral ankle sprains, one ankle would be their dominant/ preferred ankle (as indicated on their questionnaire) and the other would be their non-dominant ankle. For the group with a history of lateral ankle sprains, one ankle would be considered injured and the other uninjured. Due to the risk of participants becoming familiar with the testing procedure, the order of the testing procedure was randomised in order to reduce the risk of potential bias forming.

3.7.6 Testing procedure

The start position, a typical stance for rugby players, was consistent for all three tasks. Feet were slightly apart facing forward, hips and knees were slightly bent in a semi-squat position. Trunk was slightly bent forward with head neutral and forward. Arms were slightly bent and facing forward with hands open. Arms could be used freely for balance during the tasks. Participants were instructed verbally when to commence with the task and a whistle was used to indicate the end of the task. Participants were not involved in any form of physical activity prior to the testing procedure.

3.7.6.1 Task one: Single-leg catch-and-throw

In the game of rugby, a player cannot throw or pass the ball forward. For this reason, participants were required to catch a ball from a diagonally anterior-lateral direction and to throw the ball in a posterior-lateral direction, whilst performing a *single-leg* stance.

i) Instruction

Participants were asked to stand in the start position on the pressure mat.

ii) Action

Participants of the group with a history of lateral ankle sprains were asked to stand on their injured ankle and participants of the group without a history of lateral ankle sprains were asked to stand on their dominant ankle. For the uninvolved leg, the knee was bent to 90 degrees; the foot was facing backward and not touching the pressure mat. Once the participant was in this position, an assistant threw a rugby ball to the participant from an anterior-lateral position. The participant was required to catch the ball and throw it in a posterior-lateral direction. The participant then placed the uninjured leg on the pressure mat and the whistle indicated the task was completed.

iii) Data measurement time

Data was recorded from the time the participant was in *single-leg* stance until the time the whistle blew.

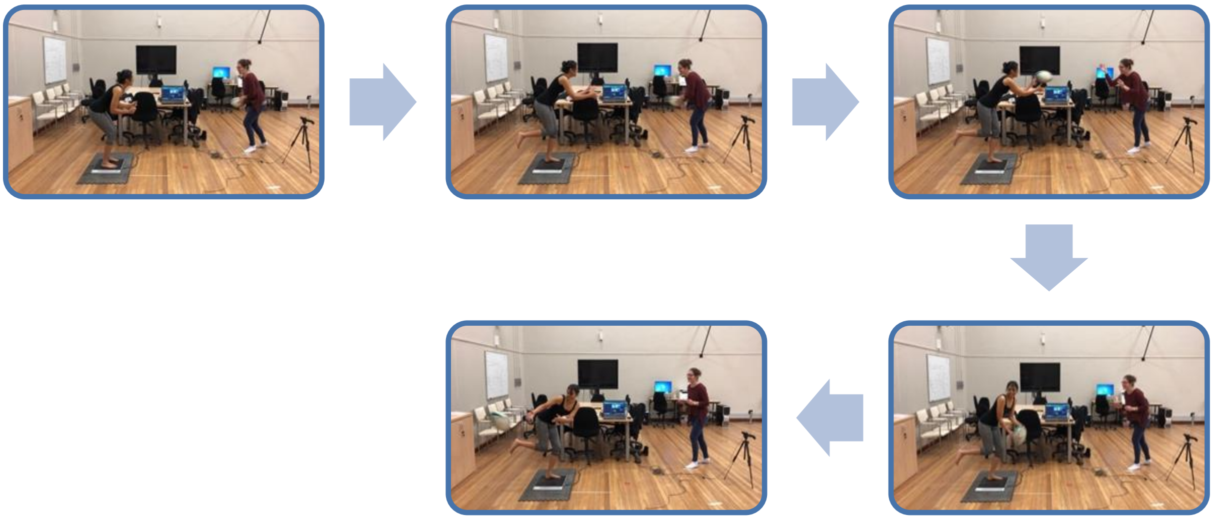

Figure 3.7: Sequencing of task one, *single-leg catch-and-throw* (pilot study)
(Permission has been granted by models in the photographs)

3.7.6.2 Task two: Single-leg jump landing

The second task required participants to stand in the start position, with the pressure mat directly in front of them. In rugby, jump landings may be required when players try to catch a ball from a height or when contesting another player for the ball.

i) Instruction

The participant was expected to hold the position for ten seconds; the whistle would signify the end and participants then placed the uninvolved leg back onto the mat when the whistle blew.

ii) Action

The participant was asked to jump forward on the pressure mat and land only on the injured ankle for the group with a history of lateral ankle sprains and the dominant ankle for the group without a history of lateral ankle sprains. For the uninvolved leg, the knee was bent to 90 degrees; foot faced backward and not touching the pressure mat.

iii) Data measurement time

Data were collected from the time the participant landed on the pressure mat in a *single-leg* stance until the time the uninvolved leg was placed on the pressure mat.

3.7.6.3 Task three: Side step

The last task required participants to stand in the start position at a 45-degree posterior-lateral angle to the pressure mat, a few meters away. In rugby, sidestepping or cutting (landing from a lateral weight shift) movements are required when players are running and suddenly need to change direction.

i) Instruction

The participant was asked to stand in the start position at a particular spot that was clearly marked.

ii) Action

The participant was asked to run towards the pressure mat, *side step* and land with the injured ankle on the mat for the group with a history of lateral ankle sprains and the dominant ankle for the group without a history of lateral ankle sprains. For the uninvolved leg, the knee was bent to 90 degrees, the foot faced backward and not touching the pressure mat.

iii) Data measurement time

Data were collected from the time the participant landed on the pressure mat until the time the uninvolved leg was placed on the pressure mat. The task was then performed from the opposite side, posterior-lateral 45-degree angle.

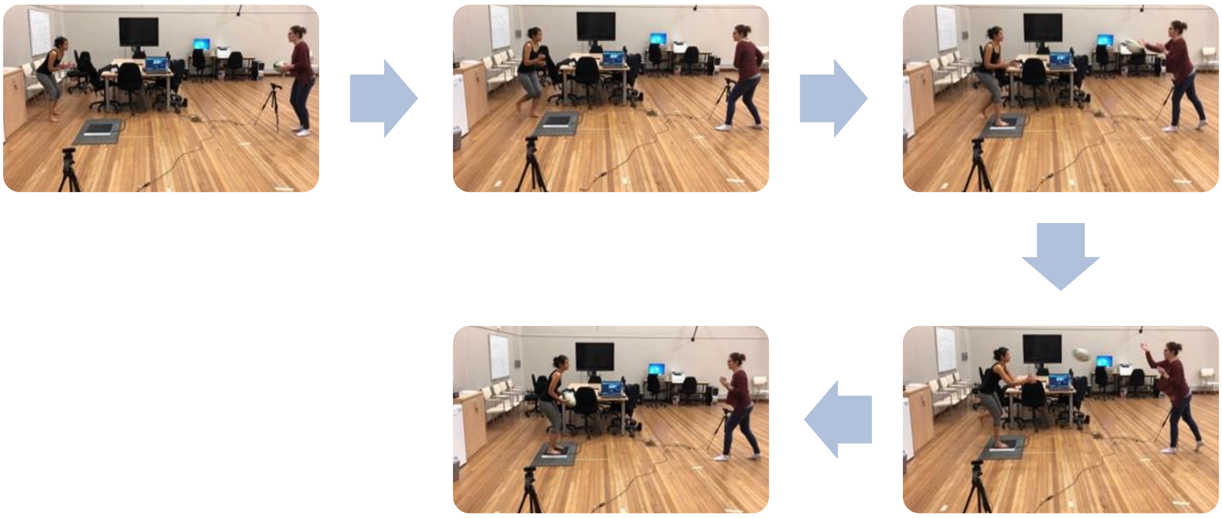

Figure 3.8: Sequencing of task three, *side step* (pilot study)
(Permission has been granted by models in the photographs)

3.7.7 Post-testing

There were no injuries involved with the testing procedure. Participants received a gift voucher as a token of appreciation for participation in the study and refreshments were served.

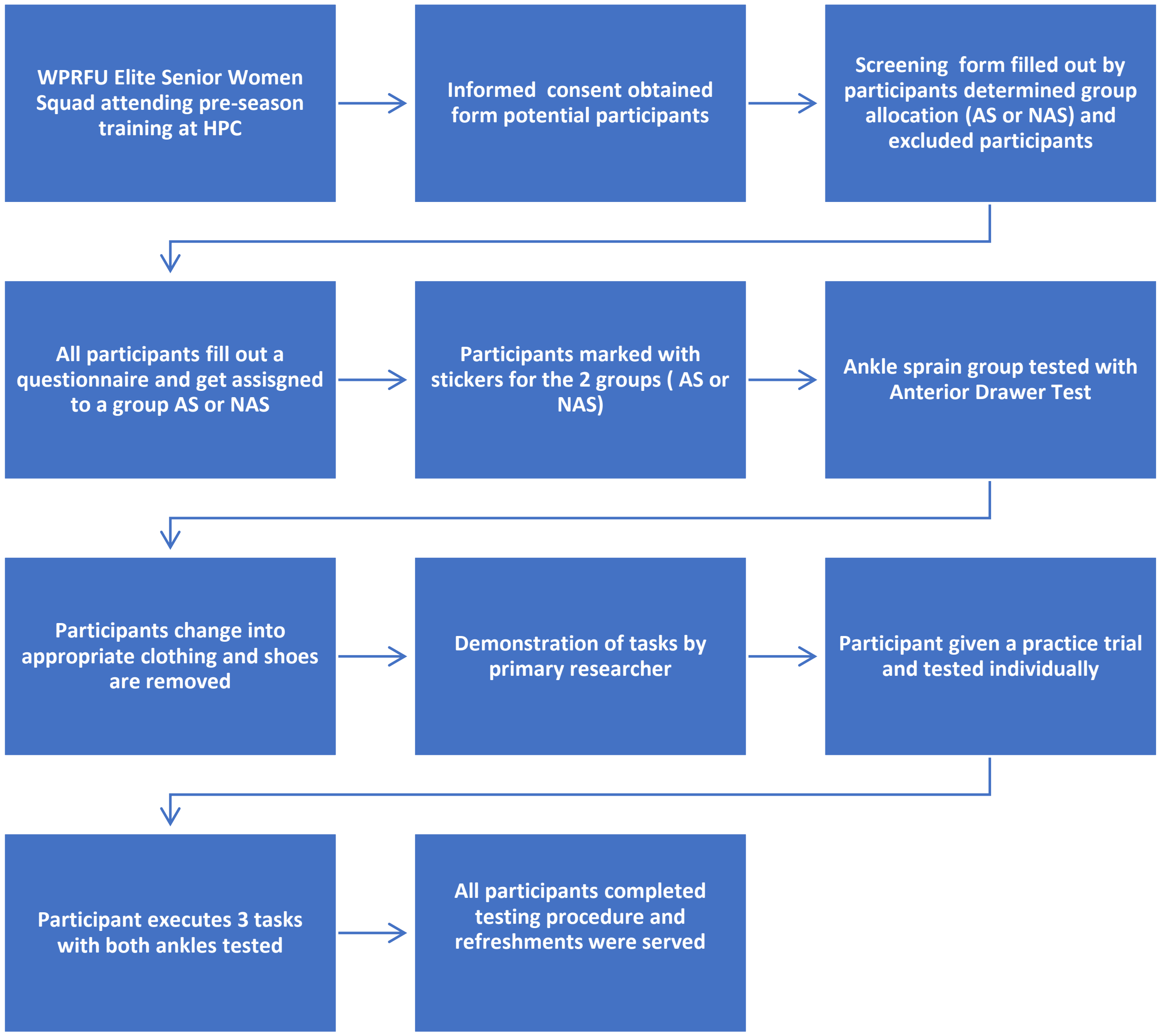

Figure 3.9: Flow chart diagram of study procedure

3.8 Pilot study

A pilot study was performed on 24 July 2018 at the Movement Analysis Laboratory at Stellenbosch University's Tygerberg campus to standardise the testing procedure and to determine the amount of time each participant needed to complete each testing procedure. It was then confirmed from the pilot study that each participant would require approximately five minutes to be tested. To test approximately 30 participants would require circa two and a half hours. The pilot also helped with the planning for data collection and determined that an assistant would be required on the day of testing to throw and catch the rugby ball as well as for the collection of the data.

3.9 Data management

The main researcher did the coding of each participant and the entering of the data. An analyst then processed the raw data, which was referenced with the study code. The ankle sprain group code was AS and the non-ankle sprain group code was NAS, followed by a numerical value. A backup was created on an external hard drive and then password protected. Access to the computer storing the data is password protected, and the computer is kept in a safe and secure location when not in use. Screening forms, questionnaires and consent forms are kept safe at the Physiotherapy Department, University of Stellenbosch, Faculty of Medicine and Health Sciences. This approach to data management ensures confidentiality, safety, and security of all data collected.

3.10 Data reduction and outcomes

Raw pressure data were measured using a 48x40 Sensel Zebris pressure plate and recorded using the MyoResearch 3.12.7 software at a sampling rate of 120 Hz. Time markers were meticulously inserted into each recording to signify the beginning and end of the *single-leg balance* period. COP data were exported into single CSV files and the raw pressure data into single XML files. These files were then imported into Matlab 2017a. COP signals were transformed to the anatomical axes (anterior-posterior and medial-lateral) from the x and y of the plate (assuming the foot was always parallel to the y-axis of the pressure plate). These signals were then used to generate COP distance, displacement, speed and velocity signals. These signals were cropped according to the manually inserted time markers. The COP outcomes (including SA) were extracted using period analysis of these generated signals. The TTB outcomes required boundary (of the foot) extraction, which was done per sample using the Sensel data from the imported XML data. The outcomes were then exported to an Excel spreadsheet that was later used in statistical analysis.

3.11 Statistical analysis

The main researcher consulted a statistician at the Biostatistics unit (Stellenbosch University) for the statistical analysis. An Excel spreadsheet of the data collected was exported to SPSS version 26 (IBM SMSS for Windows, 2019) for processing and data analysis. All descriptive data (age, weight, height, BMI, and position of play) were analysed using descriptive statistics to indicate central tendencies. Mann-Whitney calculations were performed to determine a significance difference in outcomes between the group with a history of ankle sprains and the group without a history of ankle sprains. A non-pragmatic approach was used to illustrate descriptive statistics.

3.12 Ethical and legal considerations

The protocol of this study was approved by the Health Research Ethics Committee of Stellenbosch University (Appendix 5). The project ID is 8600 and the ethics reference number is S18/10/236.

3.12.1 Informed consent

Informed consent from participants was obtained prior to the study. All the details regarding informed consent in the current study are explained in section 3.7.1.

3.12.2 Confidentiality

Personal details of the participants and data collected during the study were handled confidentially (see section 3.9).

3.12.3 Risk-benefit ratio

There was a physical risk of injury, discomfort, or pain to the participants brought on by the tasks. To reduce this risk, the medical team doctor was present in case of any emergency. However, the benefit of performing these tasks encouraged the structures surrounding the ankle joint to stabilise, which helped to improve their balance. This also served as an indicator to participants of the stability of their ankle joint and whether balance exercises should be included in their training programme.

3.12.4 Dissemination of the findings

Feedback on the findings of the study will be communicated to participants upon completion of the study via a lecture/interactive workshop to WPRFU, particularly highlighting the main findings of this study. The findings may be published in scientific journals and presented at scientific meetings or conferences.

3.13 Conclusion

This chapter detailed the methodology followed to answer the research question. A cross-sectional study design was followed and the study was conducted in a gymnasium setting. The Noraxon myoPressure™ system was utilised to capture the peak values of outcomes during balance testing.

The results obtained after having followed these methods are discussed in the next chapter (Chapter 4: Results).

CHAPTER 4: RESULTS

The results from this study should be interpreted with caution due to the finite population correction.

4.1 Socio-demographic characteristics of study participants

The intended targeted population were all WPRFU active club registered senior women for the 2019 season (n=198). An elite squad was then selected from this group and invited to participate in a pre-season training programme (n=47). In total, 31 players attended the training programme.

All participants for this study were female. In total, 31 participants complied with the inclusion criteria and they were allocated to one of two groups. The group with a history of ankle sprains (AS) consisted of 12 participants (38.7%) and the group without a history of ankle sprains (NAS) consisted of 19 participants (61.3%). The total club players for the 2018 season in the AS group were Tygerberg RFC (n=2, 16.7%), UWC RFC (n=3, 25%), Busy Bee RFC (n=6, 50%) and Unknown (n=1, 12%). The total club players for the 2018 season in the NAS group were Tygerberg RFC (n=9, 47.3%), UWC RFC (n=4, 21.1%), Busy Bee RFC (n=3, 15.8%), Blue Jets RFC (n=2, 10.5%) and Unknown (n=1, 5.3%).

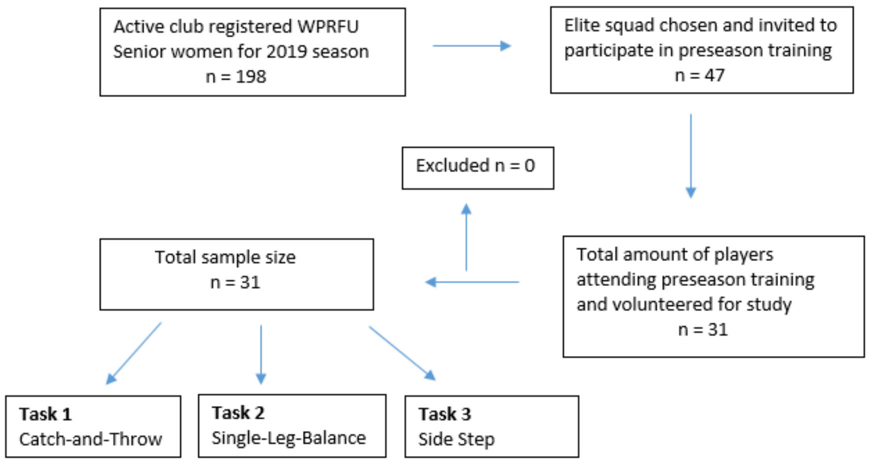

Figure 4.1: Data collection process

Sixteen (51.6%) of the participants were backline players whilst 15 (48.4%) were forward players. Of the 16 backline players, the AS group consisted of (n=7) and the NAS group of (n=9) players. Of the 15 forward players, the AS group consisted of (n=5) and the NAS group of (n=10) players. The most frequent player positions indicated by players on their questionnaires were left wing, loosehead prop, and scrumhalf, represented by three (3) participants (9.7%) respectively. The Mann-Whitney statistical test was used to assess normality of the data. The continuous variables are not normally distributed, hence, median and interquartile range (IQR) were used. The participant socio-demographics are summarised in Table 4.1.

Table 4.1: Participant socio-demographics

	Group	n	Median	IQR
Age (yrs)	AS	12	21.5	4
	NAS	19	21.0	4
Weight (kg)	AS	12	65.5	31
	NAS	19	70.0	26
Height (cm)	AS	12	157.5	11
	NAS	19	162.0	8
BMI (kg/m^2)	AS	12	24.9	7.4
	NAS	19	27.2	7.8

4.2 Symptom presentation of the ankle and non-ankle sprain groups

Participants of the AS group reported an equal amount of injuries to the left and right ankles (n=6) respectively, whereas participants of the NAS group indicated their dominant ankle to be left (n=1) and right (n=18).

Table 4.2: Ankle sprain and non-ankle sprain group limb dominance

Group	Left	Right
Ankle Sprain (AS)	n = 6	n = 6
Non - Ankle Sprain (NAS)	n= 1	n = 18

4.3 Outcome measures

The outcome measures (SA, COP Sp, TTB) are described using median and IQR because of the small group sizes (AS=12 and NAS=19). The analysis of the group comparison was not done at athlete (n=31) level but rather at leg level due to small sample size. Therefore, in total, 62 ankles were evaluated for this study (n=12 injured ankles in the AS group, n=12 uninjured ankles in the AS group, n=38 uninjured ankles in the NAS group). For the purpose of this study, the uninjured ankles per participant in the NAS group were considered independent of one another. Statistical significance of difference in outcomes between the groups was set at P-value < 0.05. The non-parametric Mann-Whitney test was applied for analysis, as variables were found to be not normally distributed.

4.3.1 Sway Area

Sway Area was assessed by participants performing three tasks, namely *catch-and-throw* (CT), *single-leg balance* (SLB), and *side step* (SS). The results of these tasks are summarised and presented in terms of median and IQR values.

Injured ankles of AS group compared to uninjured ankles of NAS group

Distributions of the Sway Area in the injured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group differed significantly (Mann-Whitney U=136.000, p=0.037) for the task *side step* Sway Area (SS/SA). However, the results of the remaining tasks (CT/SA and SLB/SA) indicated no significant statistical difference between the injured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group.

Uninjured ankles of AS group compared to uninjured ankles of NAS group

Distributions of the Sway Area in the uninjured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group differed significantly (Mann-Whitney U=118.000, p=0.012) for the task *catch-and-throw* Sway Area (CT/SA). The results of the other tasks (SLB/SA and SS/SA) indicated no significant statistical difference between the uninjured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group.

Injured ankles of AS group compared to uninjured ankles AS group

The results of the tasks performed indicated no significant statistical difference between the injured ankles of the ankle sprain group and the uninjured ankles of the ankle sprain group for all tasks (CT/SA, SLB/SA, SS/SA).

Table 4.3: Descriptive statistics for Sway Area

Task	Group	Median	IQR
CT/SA	Injured (ankle sprain)	929.23	714.25
	Uninjured (ankle sprain)	773.5	731.93
	Uninjured (non - ankle sprain)	1179.88	756.48
SLB/SA	Injured (ankle sprain)	1607.58	1087.49
	Uninjured (ankle sprain)	1068.75	788.15
	Uninjured (non - ankle sprain)	1101.63	712.94
SS/SA	Injured (ankle sprain)	3650.67	3483.15
	Uninjured (ankle sprain)	3476.50	1850.29
	Uninjured (non - ankle sprain)	2974.37	2227.82

CT/SA = Catch-and-Throw / Sway Area
SLB/SA = Single-Leg Balance / Sway Area
SS/SA = Side Step / Sway Area

The SA means per task was compared. The results indicate that for task CT (Figure 4.3), the SA values were higher in the uninjured ankles of the non-ankle sprain group and the least in the uninjured ankles of the ankle sprain group. The SLB task (Figure 4.2) indicates that the highest mean values for SA were the injured ankles of the ankle sprain group and the lowest values were in the uninjured ankles of the ankle sprain group. The means of task SS (Figure 4.4) indicates that SA values were excessively high in the injured ankles of the ankle sprain group and lowest in the uninjured ankles of the non-ankle sprain group. Overall, the SA means was the highest in the injured ankles of the ankle sprain group in two of the tasks (SLB and SS) and lowest in the uninjured ankles of the ankle sprain group in two tasks (CT and SLB). SS/SA was the only task where the mean values for the non-ankle sprain group were the lowest. The comparison of Sway Area for the tasks *single-leg balance* (SLB), *catch-and-throw* (CT), and *side step* (SS) are depicted below using mean plots.

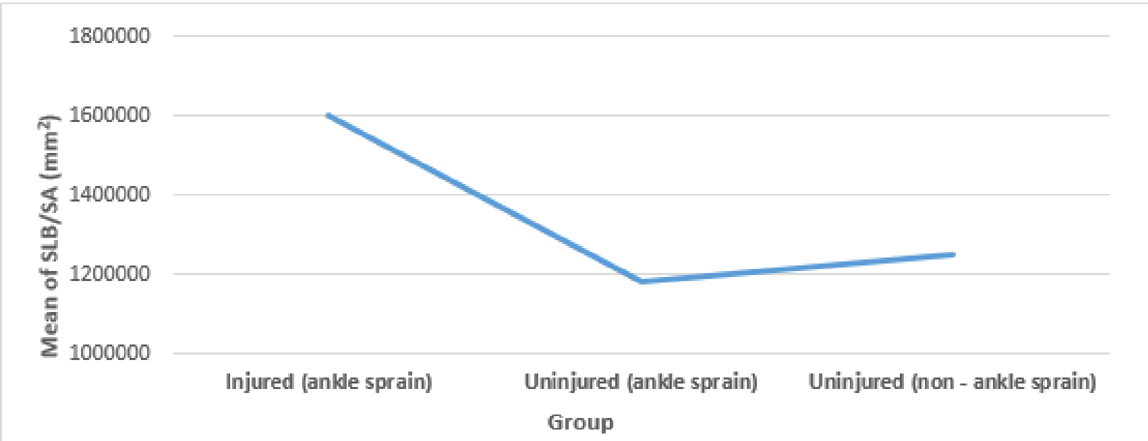

Figure 4.2: Mean plot of Sway Area for the task *single-leg balance*

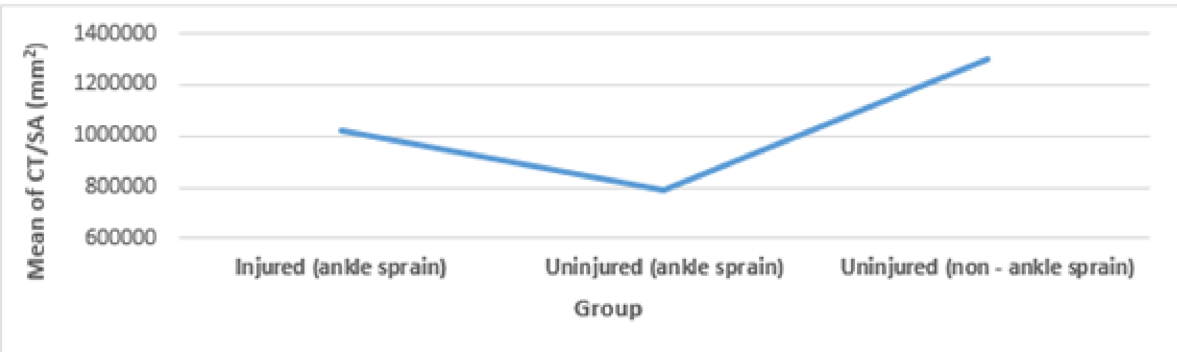

Figure 4.3: Mean plot of Sway Area for the task *catch-and-throw*

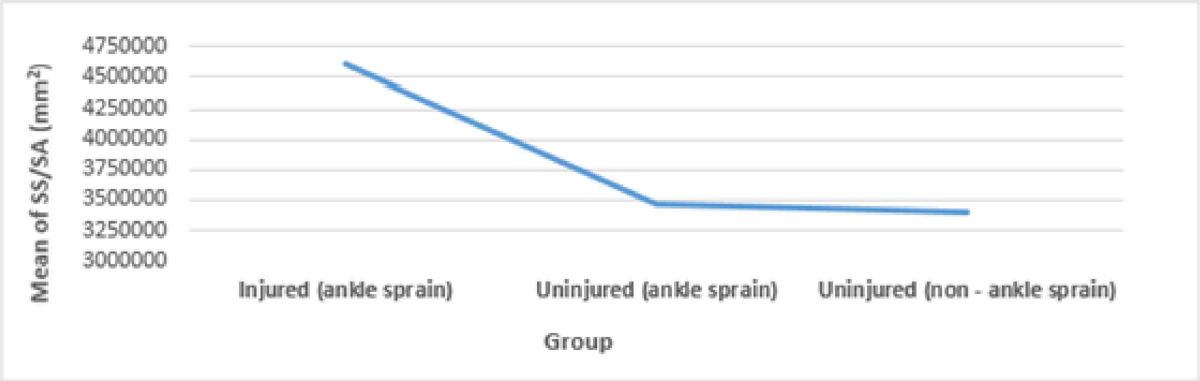

Figure 4.4: Mean plot of Sway Area for the task *side step*

4.3.2 COP Speed

COP Speed was assessed by participants performing three tasks, namely *catch-and-throw* (CT), *single-leg balance* (SLB), and *side step* (SS). The results of these tasks are summarised and presented in terms of median and IQR values.

Injured ankles of AS group compared to uninjured ankles of NAS group

Distributions of COP Sp in the injured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group differed significantly (Mann-Whitney U=110.000, p=0.007) for the task SS/COP Sp. The results of the other tasks (CT/COP Sp and SLB/COP Sp) indicated no significant statistical difference between the injured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group.

Uninjured ankles of AS group compared to uninjured ankles of NAS group

The results of the tasks performed (CT/COP Sp, SLB/COP Sp, SS/COP Sp) indicated no significant statistical difference between the uninjured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group.

Injured ankles of AS group compared to uninjured ankles AS group

The results of the tasks performed (CT/COP Sp, SLB/COP Sp, SS/COP Sp) indicated no significant statistical difference between the injured ankles of the ankle sprain group and the uninjured ankles of the ankle sprain group.

Table 4.4: Descriptive statistics for COP Speed

Task	Group	Median	IQR
CT/COP Sp	Injured (ankle sprain)	67.24	28.24
	Uninjured (ankle sprain)	80.46	30.85
	Uninjured (non - ankle sprain)	94.28	32.87
SLB/COP Sp	Injured (ankle sprain)	54.70	28.57
	Uninjured (ankle sprain)	56.60	17.82
	Uninjured (non - ankle sprain)	57.50	17.84
SS/COP Sp	Injured (ankle sprain)	291.45	60.45
	Uninjured (ankle sprain)	267.41	59.35
	Uninjured (non - ankle sprain)	240.50	83.95

CT/COP Sp = Catch-and-Throw / COP Speed
SLB/COP Speed = Single-Leg Balance / COP Speed
SS/COP Sp = Side Step / COP Speed

4.3.3 Time-to-Boundary

Time-to-Boundary was assessed by participants performing three tasks, namely *catch-and-throw* (CT), *single-leg balance* (SLB), and *side step* (SS). The results of these tasks are summarised and presented in terms of median and IQR values.

Injured ankles of AS group compared to uninjured ankles of NAS group

Distributions of the TTB in the injured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group differed significantly (Mann-Whitney U=127.000, p=0.022) for the task *catch-and-throw* (CT/TTB) (mean minimum). There was also a statistical difference in the distribution for the task SS/TTB between the injured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group in the mean minimum (Mann-Whitney U=93.500, p=0.002) and standard deviation minimum values (Mann-Whitney U=107.500, p=0.006). The results of the other tasks **(**CT/TTB and SLB/TTB) indicated no significant statistical difference between the injured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group.

Uninjured ankles of AS group compared to uninjured ankles of NAS group

The results of the tasks performed (CT/TTB, SLB/TTB, SS/TTB) indicated no significant statistical difference between the uninjured ankles of the ankle sprain group and the uninjured ankles of the non-ankle sprain group.

Injured ankles of AS group compared to uninjured ankles AS group

The results of the tasks performed (CT/TTB, SLB/TTB, SS/TTB) indicated no significant statistical difference between the injured ankles of the ankle sprain group and the uninjured ankles of the ankle sprain group.

Table 4.5: Descriptive statistics for Time-to-Boundary

Descriptive Statistics for Time - To - Boundary (TTB)

Group	Task								
	Catch-and-Throw (CT)			Single-Leg Balance (SLB)			Side Step (SS)		
	Abs min	Mean min	SD min	Abs min	Mean min	SD min	Abs min	Mean min	SD min
Injured AS median	0.39	1.39	0.99	0.22	2.02	2.10	0.17	0.29	0.10
IQR	0.11	0.58	0.78	0.12	2.61	8.19	0.13	0.018	0.19
Uninjured AS median	0.43	1.13	0.73	0.23	2.68	2.66	0.20	0.50	0.22
IQR	0.19	0.82	1.33	0.11	1.86	2.65	0.11	0.38	0.32
Uninjured NAS median	0.31	0.97	0.72	0.24	2.38	2.39	0.19	0.55	0.41
IQR	0.20	0.43	0.74	0.12	1.16	1.63	0.10	0.45	0.46

AS = ankle sprain
NAS = non - ankle sprain

A summary of the results for each outcome is represented below.

Table 4.6: Summary of results for each outcome

	Sway Area		
TASK	Group 1	Group 2	Group 3
Catch-and-Throw	–	↑	–
Single-Leg Balance	–	–	–
Side Step	↑	–	–

	COP Speed		
TASK	Group 1	Group 2	Group 3
Catch-and-Throw	–	–	–
Single-Leg Balance	–	–	–
Side Step	↑	–	–

	Time - to - Boundary		
TASK	Group 1	Group 2	Group 3
Catch-and-Throw	↑	–	–
Single-Leg Balance	–	–	–
Side Step	↓	–	–

Key :

↑ Increased value in statistical difference
↓ Decreased value in statistical difference
– No statistical differences

Group 1 : Injured (Ankle Sprain) vs. Uninjured (Non - Ankle Sprain)
Group 2 : Uninjured (Ankle Sprain) vs. Uninjured (Non - Ankle Sprain)
Group 3 : Injured (Ankle Sprain) vs. Uninjured (Ankle Sprain)

CHAPTER 5: DISCUSSION, LIMITATIONS, CHALLENGES AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a discussion of the key findings of the study, in light of the current literature. The main objective of the study regarding comparing the differences in balance outcomes between rugby players with and without a history of lateral ankle sprains is discussed. Further, the clinical applicability as well as the limitations of the study findings is presented.

5.2 Main objective of the study

The main objective of this study was to ascertain if there are differences in objective balance between elite female rugby players with and without a history of lateral ankle sprains. We measured dynamic balance outcomes using Sway Area (SA), Centre of Pressure Speed (COP Sp), and Time-to-Boundary (TTB). The variables of balance between the ankle sprain (AS) and non-ankle sprain (NAS) groups for COP Speed were mostly similar for the three tasks tested, with an exception in the *side step* task. The main differences between the ankle sprain and non-ankle sprain groups that were statistically significant, were found in SA and TTB outcomes during the *catch-and-throw* tasks. All tasks developed for this study were dynamic balance-oriented and rugby specific. *Catch-and-throw* depicts the catching and throwing (passing) of a rugby ball, *single-leg balance* represents balancing on one leg after a *jump landing*, and *side step* depicts a cutting movement. To our knowledge, this is the first study in South Africa to report on the differences of dynamic balance outcomes in female rugby players with and without a history of lateral ankle sprains.

5.2.1 Sway Area

We found statistically significant differences (p=0.04) and (p=0.01) in Sway Area for the tasks *catch-and-throw* and *side step* respectively. Examination of the SA mean plots for all three tasks indicated that Sway Area was higher among the non-ankle sprain group during the *catch-and-throw* tasks compared to the *single-leg balance* and *side step* tasks, whereas the Sway Area was higher on the injured ankles of the ankle sprain group. Sway Area measures the ability of an individual to stand still (Schubert & Kirchner, 2014; Gerbino et al., 2007). It can be used to measure static balance after a jump (Ricotti, 2011) and has an indirect relationship to static balance (Ras & Puckree, 2014). This implies that high sway scores typically indicate poorer balance and low sway scores indicate better balance. Researchers such as Chander et al. (2014), Mancini and Horak (2010), Zemková (2011), Gerbino et al. (2007), and Hrysomallis et al. (2006) agree that postural sway is indicative of balance in that when a player displays more postural sway, it is an indication of instability in standing, and alternatively, when a player displays less postural sway, it implies that they are more stable in standing. Players are most likely to have poorer balance (high sway scores) as a result of a disruption of proprioception due to injury (Han et al., 2015; Schifton et al., 2015; Hammami et al., 2014; Ras & Puckree, 2014; McKeon & Hertel, 2008; Akbari et al., 2006). However, poor balance may also be a manifestation of disruption to other sensory/afferent pathways.

Therefore, our findings on high Sway Area values among the ankle sprain group are in agreement with previous findings by Gerbino et al. (2007), as the injured group is expected to display poorer balance. Sensorimotor deficits caused by ligament injury following an ankle sprain may lead to impaired postural control (O'Driscoll & Delahunt, 2011). The expected ligament healing timeframe can take up to one year after trauma (Petersen et al., 2013); however, if players return to rugby before full recovery, they could still present with sensorimotor deficits at testing. Previous studies in agreement with our current findings (Schifton et al., 2015; Han et al., 2015; Hubbard & Hicks-Little, 2008) further indicate that ankle sprains are associated with poor balance because of ligament damage at the joint.

The high Sway Area values among the non-ankle sprain group indicate poorer postural control and this is an unexpected finding because essentially, all participants of this group indicated that they did not have an ankle sprain in the past 18 months. Sway Area values were therefore expected to be lower than those in the AS group since high Sway Area scores are typically indicative of poorer balance (Ras & Puckree, 2014; Gerbino et al., 2007). Similarly, a cross-sectional survey study by Koenig and Puckree (2015) measured balance in female soccer players using Sway Index (synonymous with Sway Area) as a measurement of balance, and similar results were found between the injured and uninjured players.

There was no difference in Sway Index scores between injured and uninjured players in some test conditions. One test condition showed a higher score in the injured group and one test condition showed a higher value in the uninjured group. The researchers attributed the insignificant differences to the unequal group sizes used for the statistical analysis. They concluded that one-third of the participants were injured in comparison to two-thirds of the participants who were uninjured, resulting in inequality in terms of group sizes for comparison. Similarly, in the current study, the ankle sprain group consisted of 38.7% of the total participants in comparison with the non-ankle sprain group, which consisted of 61.3%. The inequality in our group sizes could be a possible contributing factor to the insignificant results and the higher Sway Area values in the uninjured group. Another possibility to the insignificant findings is the indication of the participants that they did not have an ankle sprain the previous 18 months; however, it was not established in this study whether they had an ankle sprain prior to the 18 months or no history of an ankle sprain at all. The 18-month timeframe was conveniently chosen for measurement purposes.

Clinically, Sway Area measurements can be used as an indication of postural stability in those with and without a history of ankle sprains for balance retraining following an ankle sprain as well as proprioceptive training as a preventative measure in rugby players. Therefore, further prospective research studies using relatively larger samples are needed to investigate this outcome.

5.2.2 COP Speed

We found a statistical significant difference (p=0.01) in COP Speed only between the ankle sprain and non-ankle sprain group for the task *side step*. For the other two tasks, we found no difference. COP Speed has been used previously by researchers to examine differences in COP measurements (Troester et al., 2018; Steib et al., 2013; Palmieri et al., 2002). An increase in COP Speed is considered to represent a decreased ability to control posture and a decrease in COP Speed is considered to represent an increase in ability to maintain upright stance (Troester et al., 2018; Palmieri et al., 2002).

If the above definition is considered accurate, the high COP Speed values indicate poor postural control in the AS group. This is in agreement with previous research findings, as ankle sprains are known to affect balance negatively (Han et al., 2015; Schifton et al., 2015). Studies by Troester et al. (2018) and Steib et al. (2013) recommend COP Speed as a reliable parameter of balance. Despite this finding, in our study, COP Speed showed no significant difference for the other two tasks. A possible reason for these insignificant findings might be the result of the small sample size enrolment (n=12 for AS group; n=19 for NAS group) in this study. Power analysis was calculated for this study (power=80%) and the total required sample needed for a statistical difference was 50. However, due to the smaller target population size, a finite population correction formula was used and the minimum sample size needed for a significant statistical difference was adjusted to 24. Therefore, larger sample studies are needed to investigate this outcome. Another possible explanation could be that each task was performed at a different speed/velocity, which could make detecting differences more subtle.

Clinically, COP Speed is considered a valuable tool for pre-season assessment and may be utilised further before and after an injury as a measure of indicating when a player is ready for safe return to play (Palmieri et al., 2002).

5.2.3 Time-to-Boundary

We found a statistical significant difference (p=0.02) in Time-to-Boundary (mean minimum) between the AS and NAS group for the task *catch-and-throw* as well as in Time-to-Boundary (standard deviation minimum) for the task *side step* (p=0.01). For the task *catch-and-throw*, the ankle sprain group displayed an increase in value in comparison to the non-ankle sprain group. For the *side step* task, the ankle sprain group displayed a decrease in value in comparison to the non-ankle sprain group. Time-to-Boundary measures provide information about COP excursions in relation to the boundaries of the borders of the foot (Hertel & Olmsted-Kramer, 2007). It measures the time taken for the participant to make postural changes following a perturbation, whilst maintaining upright stance (Flanagan et al., 2008; Brown & Mynark, 2007; Hertel & Olmsted-Kramer, 2007).

The lower Time-to-Boundary values in the ankle sprain group for the *side step* task are in agreement with literature (Wikstrom et al., 2010; McKeon & Hertel, 2008; Hertel & Olmsted-Kramer, 2007). Lower TTB values indicate postural instability. Higher TTB values in the ankle sprain group for the *catch-and-throw* task indicate that the ankle sprain group had better balance for this task than the non-ankle sprain group. The reliability of TTB as a tool to measure balance varies in literature. Previous cohort studies by Hertel and Olmsted-Kramer (2007) and Steib et al. (2013) are in favour of TTB as a reliable measure to assess balance. Similarly, Steib et al. (2013) assessed the effect of exercise on balance by measuring TTB differences in ankle sprain and non-ankle sprain groups. Participants performed a unilateral jump-landing task on a force plate. Reliability ranged from moderate to excellent and therefore considered a reliable measure to assess balance. In contrast to this finding, a recent study by Troester et al. (2018) suggests that TTB (in comparison with sway velocity) should be used with caution due to differences in reliability and precision between the dominant and non-dominant leg when testing balance in injury free rugby players. Level of evidence is in support of the cohort studies. Despite the reliability of TTB, no significant differences were found for the other tasks in our study.

A possible explanation is that the small sample size may have contributed because of the small participant numbers in the ankle sprain group in comparison with the non-ankle sprain group. It should also be noted that assessment of balance occurred at limb level and not at participant level (AS n=12, NAS n=19). For the purpose of this study, it was therefore assumed that the uninjured ankles from the non-ankle sprain group were independent of each other for testing purposes. The total ankles assessed for this study were 62, namely injured ankles for the ankle sprain group (n=12) and uninjured ankles for the ankle sprain and non-ankle sprain group (n=50).

Clinically, TTB can be used as an objective outcome in rehabilitation to quantify balance, as measurements can be recorded prior to commencement and upon completion of a balance exercise programme. Higher TTB values indicate more postural stability and lower TTB values indicate less postural stability. The aim would therefore be to see that the TTB values improve as treatment progresses, as this is indicative of an improvement in postural stability.

5.3 Study demographics

The ankle sprain and non-ankle sprain groups were similar in age, but the weight, height, and BMI were slightly higher in the non-ankle sprain group. All participants of this study were female (n=31) and the participation rate was 100%. There was no restriction on the number of participants included in this study. All participants performed the required tasks and no adverse reaction to testing was experienced. Sample size in the AS group was smaller (n=12) than the NAS group (n=19). Chander et al. (2014) evaluated balance amongst female soccer players (n=10), volleyball players (n=6), and dancers (n=5) with similar demographics. The number of participants in Hertel and Olmsted-Kramer’s (2007) study were fifteen and nine for the ankle sprain and control groups respectively. Since literature on women in contact sport is limited, it appears that smaller sample sizes are more common. Smaller sample sizes are not a full representation of the target population and a limitation of this study is that generalisations cannot be made.

5.4 Response rate

The intended targeted population total of active club-registered senior women rugby players was 198. An elite squad of 47 players (25%) was invited to attend senior women training. The total amount of players who attended the training was 31 (66%). None of the participants complied with the exclusion criteria hence the sample size of 31. The response rate was 100%.

5.5 Clinical applicability

Sway Area, COP Speed, and Time-to-Boundary outcomes can be used in a clinical setting to objectively quantify balance in rugby players with and without a history of lateral ankle sprains. It may be beneficial in pre-season assessment where baseline measurements can be recorded. It may also be measured prior to an injury and post-injury for safe return to play as well as during rehabilitation of ankle sprains as a measure of postural stability with balance retraining. These balance outcomes may also be utilised in identifying rugby players with poorer balance at risk of developing an ankle sprain and who may benefit from a proprioceptive balance training programme as a preventative measure for ankle sprains. Sway Area and Time-to-Boundary in particular demonstrated statistically significant results and therefore the researcher would recommend the utilisation of these outcome measures clinically to quantify balance. The task *catch-and-throw* is recommended as a balance-orientated task for rugby.

5.6 Limitations

Our study findings have limitations that should be taken into consideration. The cross-sectional study design that was used does not allow any cause-and-effect conclusions to be made about ankle sprains and balance. Another limitation of this study was the relatively small sample size of 31 participants in total. The number of participants per group was unequal. The AS group size was smaller (n=12) in comparison with the NAS group size (n=19). Gerbino et al. (2007) compared balance between female dancers and soccer players with equal-sized sample groups (n=32), whilst Hertel and Olmsted-Kramer (2007) compared balance between an ankle sprain group (n=15) and a control group (n=9). Since the objective of this study was to evaluate the difference in balance outcome measures, it could be the reason why there were statistically significant results only in some tasks, possibly due to the small size of the ankle sprain group.

The non-ankle sprain group was also not clearly defined for this study. The participants of the non-ankle sprain group were allocated to that group because they indicated on the questionnaire during the screening process that they did not have an ankle sprain in the past 18 months. However, it is possible that the participants of this group could have had an ankle sprain older than 18 months. Ideally, it would have been more beneficial to have three groups for comparison – an ankle sprain group, a group who had ankle sprains older than 18 months, and a group who had no history of ankle sprains. Due to the small squad size in women's rugby, this option would then result in an even smaller group comparison. It was for this reason that we opted to use two groups instead for data collection.

Another limitation is that the ankle sprain injuries and limb dominance were self-reported by players. The researchers of this study did not have detailed information on the severity or prior management of injuries such as rehabilitation for the ankle sprain group. Limb dominance for the non-ankle sprain group was also not controlled, which could have influenced the balance outcomes. Although participants were asked to indicate on their questionnaire if they experienced any ankle pain, the researcher failed to exclude other areas of pain or injury that could have contributed to their balance being affected.

The natural foot position of the participants' feet was not evaluated prior to the testing procedure. If a participant altered their natural foot position to ensure they were in the right position for testing, it could have an impact on the results of the test. Certain tasks could be seen as better predictor of poor ankle instability as opposed to others.

An additional contributing factor was the median age of the 21-year age group. During the data collection process, the attendance of players was lower than expected to previous years, as indicated by WPRFU staff. Grievances of senior players with the Union resulted in players delaying their commencement of pre-season training. As a result, most participants were junior (under 18 years of age) players who were now eligible to attend senior women training for the 2019 season. A systematic review by King et al. (2019) reports that age may be a contributing factor to injury risk. Older players have longer playing time and therefore more exposure to contact in rugby, which can increase their risk of injury. Therefore, since the mean age of the non-ankle sprain group was 21, it can be suggested that they have had less playing experience and on-field time, resulting in less contact, which minimises their injury risk. This could be a possible explanation for the larger sample size in the non-ankle sprain group.

Another limitation is that one of the outcome measures proposed to be used in this study (DPSI) was based on force data calculations and since we used a pressure plate for this study, an alternative similar measure (COP Sp) was instead utilised. In future, it would help to establish outcome measure calculations before data collection.

There may also be a degree of reporting bias with respect to information relating to the participants' history of their ankle sprain. Participants may have failed to disclose information accurately relating to their injury status.

It is also important to note that the main researcher for this study is part of WPRFU senior women management team. Although a potential conflict of interest could be present, the researcher did not receive any funding from the Union to conduct the study, and the aim of this research was purely to add to the limited pool of knowledge on women's rugby in literature.

5. 7 Challenges

The small sample size can be attributed to the non-attendance of players. A total of 47 players were expected at pre-season testing, however, only 31 attended. The reasons as communicated by the team management were injuries from the previous season, transport difficulties, and lack of interest at the start of the season. Some players were not able to train after sustaining injuries in their previous season, which ruled them out at the start of pre-season training. Players who required immediate surgery and those who awaited results of scans for surgery did not attend the pre-season training. Another challenge for the team was transport to the training venue. The Union allocates money for transport in the form of a lift club whereby drivers are paid to bring the players to training. This may include university transport, club transport or parents for players who live a distance from training. Delayed payment from the Union to the drivers resulted in players not being transported to training and therefore resulted in a smaller squad size. Another contributing factor to the challenges experienced in the senior women team is the lack of interest at the start of a season. Pre-season training requires cardiovascular fitness, weight training, and sport-specific drills and this intensive program may deter players at the start of a season.

5. 8 Recommendations for future research

Prospective cohort studies with larger sample sizes can be conducted pre- and post-season to determine the effect of a balance exercise programme on ankle sprain injuries using a force or pressure plate, since COP data are reliable in balance testing.

Future studies are encouraged to investigate objective balance testing in junior (under 18 years) rugby players, since this age group feeds into the senior women team. Junior teams tend not to have specialised professionals such as a team doctor, physiotherapist, and strength and conditioning coach as part of their team management. The advantage of the elite senior team is that players have access to medical staff, resources, high performance gymnasiums, and better player management from an injury prevention perspective. Therefore, younger players may not have sufficient knowledge in treating and preventing injuries, and they may not have been advised on the benefit of proprioceptive training programmes as a measure of improving balance.

CHAPTER 6: CONCLUSION

The main objective of this study was to ascertain the differences (if any) in objective balance variables between elite female rugby players with and without a history of lateral ankle sprains. Our findings show a significant difference in increased Sway Area and Time-to-Boundary among the ankle sprain group compared to the non-ankle sprain group for the tasks *catch-and-throw* and *side step*. There was also a significant difference in increased COP Speed among the ankle sprain group compared to the non-ankle sprain group. All other outcomes showed insignificant differences between the two groups.

Our findings are important as they add to the evidence base, suggesting that balance can be objectively tested and measured among female rugby players with balance impairments as a result of lateral ankle sprains. To the best of our knowledge, no other study has objectively investigated the differences in dynamic balance outcomes among elite female rugby players in South Africa. Our findings support the use of pressure plates in objective dynamic balance testing, thereby providing significant data by informing clinicians of the monitoring progress of a rehabilitation programme as well as developing a safe return-to-play protocol. The findings of this study may also assist clinicians or sport professionals with identifying players whose balance may be impaired following an ankle sprain and who may benefit from a balance training programme either pre-season or during the season, with the aim of reducing the risk of secondary ankle sprains. Additionally, it may also create awareness of the prevention of primary ankle sprains among players who have not had an ankle sprain before. Since there is a lack of evidence-based guidelines on return-to-play protocols, clinicians or sport professionals may objectively assess the progression of a player through a rehabilitation programme and evaluate the player’s readiness to safe return to play. Future studies may explore the effect of a balance intervention programme in female rugby players with and without a history of ankle sprains.

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APPENDIX 1: PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR PARTICIPATION IN THIS STUDY

Dear participant

My name is Melissa Martin and I am a Master's in Physiotherapy student at the University of Stellenbosch. I would like to invite you to participate in a research project that aims to determine if there are differences in objective balance outcomes between elite female rugby players with and without a history of lateral ankle ligament sprains. The study has also been approved by the Health Research Ethics Committee of Stellenbosch University.

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My co-supervisor's details: Dr N. Tawa, Jomo Kenyatta University of Agriculture & Technology
Email: nassibtawa@gmail.com

The next section will provide you with more information and explain what will be required of you in this study. Once you have read and understood and would like to participate in this study, please complete the declaration at the end. This will be your consent to participate in this study. You will also be provided with your own copy of this consent form. It is also your right to stop participating in this study at any point, should you wish to do that.

<u>What is a lateral ankle sprain?</u>

A sprain occurs when your ankle rolls outward causing the ligaments on the outside of your ankle to either overstretch or tear.

<u>What symptoms could you experience if you sprained your ankle?</u>

- Pain
- Swelling
- Bruising

- Limited movement
- stiffness
- Ankle may feel unstable
- Walking and running may also be painful

Why is this study being done?

This study is being done to determine if there are any differences in balance outcome measures between those who have sprained their ankle and those who have not sprained their ankle. Most research has also been based on male rugby players as subjects and my aim is to report on women rugby players as subjects.

What will be required of me if I should participate in this study?

After you sign this consent form, you will be agreeing to participate in this study. You will be required to fill out a screening form and a short questionnaire, which should not take more than 10 minutes to complete. You will then be assigned to one of two groups and allocated a colour sticker and number. This will be to indicate your group to which you belong as well as the sequence in which you will be tested. I will explain and demonstrate the three tasks required for this study. The tasks are easy to perform, easy to understand and related to rugby so you should not have difficulty performing them. You will perform the three tasks, firstly on your injured ankle (for those who have a history of lateral ankle sprains) or the preferred ankle (for those who do not have a history of lateral ankle sprains) and then on the other ankle. The testing procedure should take about five minutes to complete.

Are there any risks involved in taking part in this research?

You will be required to stand on one leg for balance as well as jump and land on one leg. There is a risk of landing incorrectly or losing your balance. It is therefore vital that you watch the demonstration that I perform before the testing and ask any questions if you unsure.

Are there any benefits?

Yes, you may benefit from this. By performing these tasks, you will be encouraging the structures around your ankle joint to stabilise, thereby improving your balance. It may also be an indication to you of how stable or unstable your ankle may be and whether you need to include these types of exercises in your pre-season training programme.

Will I receive payment for participation?

As a token of my appreciation for agreeing to participate in this study, you will receive a gift voucher to the value of R50. Refreshments will also be provided.

How will my information be protected?

Your questionnaire will not have your name on it, instead, you will be allocated a number and we will use your number to reference your information. All your information will be kept in the strictest confidence. All consent forms and questionnaires will also be kept safe at the Physiotherapy Department, University of Stellenbosch.

Declaration: I have had all the above information explained to me and I understand the explanation. I hereby grant consent to the researcher to participate in this study.

Participants name ____

Signature of participant ____________________ Date __________________

APPENDIX 2: QUESTIONNAIRE

Questionnaire

If you are willing to participate in this study, please complete the attached questionnaire. It will not take more than 10 minutes of your time. Please complete all sections.

Study title: The differences in objective balance outcomes between elite female rugby players with and without a history of lateral ankle sprains

Section 1: Demographic player profile

Study code _______________

Age ______________________ Date of Birth _____________

Weight _______ kilograms (To be measured in the gym by principal investigator or assistant)

Height________ metres (To be measured in the gym by principal investigator or assistant)

1. Which club were you registered at for the 2018 rugby season? _________________________

2. How long are you playing rugby? __________________________ (in years)

3. How long are you playing senior women rugby? ____________ (in years)

4. What is your primary position? **Forward** ______ **Back** __________

5. If you are a **forward player**, please circle what your specific position is.

- Loosehead prop
- Hooker
- Tighthead prop
- Left lock
- Right lock
- Left flanker
- Right flanker
- Number eight

6. If you are a **backline player**, please circle what your specific position is.

- Scrum-half
- Fly-half
- Left-wing
- Left center
- Right center
- Right wing
- Fullback

7. Is this the first time you are attending a high performance training programme hosted by WPRFU?   Yes/ No

8. If no, how many times have you attended before today? ___________

9. Have you ever been selected to attend a South African Rugby Union (SARU) high performance training programme? Yes/No

11. If yes, how many times have you attended? _________

Section 2: Medical details (Please circle where appropriate)

12. Are you experiencing any pain in your ankles today? Yes/No

13. Do you have any swelling in your ankles today? Yes/No

14. Are you experiencing any dizziness or unsteadiness on your feet today? Yes / No

15. Is there a medical reason that may prevent you from participating in this study? Yes /No

16. If yes, please state the reason ____

Section 3: Ankle Sprain History (Please circle where appropriate)

17. Have you had a lateral ankle sprain in the past 18 months in either ankle? Yes/No

18. If yes, please circle which ankle(s) you have sprained. Left/Right/Both

19. Please indicate the number of sprains in each ankle in the past eighteen months
    Left __________ Right ____________

20. Briefly describe how the ankle sprain(s) occurred below:

____

____

____

21. If you have not sprained your ankle, please circle which is your preferred ankle?
    Left/Right

APPENDIX 3: SCREENING FORM

Dear participant

Thank you for your interest in our ankle sprain study. Attached is a short list of questions that we would like you to answer. This serves as an initial screening to see whether you are eligible to participate in the next step of the research process. Please complete the form.

Name: …………………………………   Date: ……………………………

Age: ……………….   DOB……………………………..

Which rugby club were you registered at in 2018? ....

Please circle your response

1. Have you had a lateral ankle sprain in the past eighteen months? Yes /No

2. Have you experienced any of these symptoms in the past 3 months?
   - Pain in the injured ankle Yes /No
   - Swelling in the injured ankle Yes /No
   - Dizziness Yes /No
   - Unsteadiness on your feet Yes /No
   - Numbness or tingling in your feet Yes /No

3. Have you had a concussion in the past 3 months? Yes /No

APPENDIX 4: WPRFU CONSENT FORM

W.P. RUGBY

19 September 2018

Ms Melissa Martin
PO Box 6097
Parow East
7501

PERMISSION TO CARRY OUT A RESEARCH STUDY

Dear Madam

As Western province Rugby Football Union (WPRFU), we herewith grant permission that you may conduct your research study with our WP Women's Rugby elite squad members. We confirm the total number of athletes in the group are between 30 and 40 members.

We further confirm that permission will be sought to conduct your study at the WP Rugby High Performance Centre (HPC) situated on the corner of Voortrekker and Duminy streets in Bellville.

This permission is in line with the requirements of your Masters in Physiotherapy degree and in reply to your request to conduct such a research study within the women's rugby division of WPRFU.

It is our strong belief that your research study will make a mutually beneficial contribution to the women's rugby sector within our jurisdiction and also contribute positively to fulfilling the requirements of your studies.

We wish you all the best with your endeavours.

Kind regards

Danny Jones
GM Amateur Rugby

P.O. Box 66, Newlands, 7725
Newlands Terraces, 8 Boundary Road, Newlands, 7700

Tel (021) 659 4500
Fax (021) 659 4501
Internet: www.wprugby.com

APPENDIX 5: ETHICS APPROVAL

UNIVERSITEIT
STELLENBOSCH
UNIVERSITY

Approved

Response to Modifications

21/12/2018

Project ID: 8600

HREC Reference #: S18/10/236

Title: The differences in objective balance outcomes between elite female rugby players with and without a history of lateral ankle sprains

Dear Miss Melissa Jo-Ann Martin,

The **Response to Modifications** received on 12/12/2018 20:28 was reviewed by members of the **Health Research Ethics Committee 2 (HREC 2)** via Minimal Risk Review procedures on 21/12/2018 and was approved.

Please note the following information about your approved research protocol:

Protocol Approval Period: This project has approval for 12 months from the date of this letter.

Please remember to use your HREC reference number (S18/10/236) on any documents or correspondence with the HREC concerning your research protocol.

Please note that this decision will be ratified at the next HREC full committee meeting. HREC reserves the right to suspend approval and to request changes or clarifications from student applicants. The coordinator will notify the applicant (and if applicable, the supervisor) of the changes or suspension within 1 day of receiving the notice of suspension from HREC. HREC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

After Ethical Review:

Please note a template of the progress report is obtainable on https://applyethics.sun.ac.za/Project/Index/12369 and should be submitted to the Committee before the year has expired. The Committee will then consider the continuation of the project for a further year (if necessary). Annually a number of projects may be selected randomly for an external audit.

Provincial and City of Cape Town Approval

Please note that for research at a primary or secondary healthcare facility permission must still be obtained from the relevant authorities (Western Cape Department of Health and/or City Health) to conduct the research as stated in the protocol. Contact persons are Ms Claudette Abrahams at Western Cape Department of Health (healthres@pgwc.gov.za Tel: +27 21 483 9907) and Dr Helene Visser at City Health (Helene.Visser@capetown.gov.za Tel:+27 21 400 3981). Research that will be conducted at any tertiary academic institution requires approval from the relevant hospital manager. Ethics approval is required BEFORE approval can be obtained from these health authorities.

We wish you the best as you conduct your research.

For standard HREC forms and documents please visit: https://applyethics.sun.ac.za/Project/Index/12369

If you have any questions or need further assistance, please contact the HREC office at 021 938 9677.

Yours sincerely,

Francis Masiye,

HREC Coordinator

Health Research Ethics Committee 2 (HREC 2).

Federal Wide Assurance Number: 00001372

Institutional Review Board (IRB) Number: IRB0005239

The Health Research Ethics Committee complies with the SA National Health Act No.61 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 Part 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2015 (Department of Health).