The relationship between postural stability, sway, balance, and injury in adolescent female soccer players in the eThekwini District of KwaZulu-Natal

By

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I, Jean-Pierre Koenig, do declare that this dissertation is representative of my own work in both conception and execution (except where acknowledgements indicate to the contrary)

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Dedication

I dedicate this work to our Lord and Saviour Jesus Christ without whom I would not have been able to complete this dissertation.

To my family, Marcel, Celia, Nathalie and Marcienne. Thank you for carrying me when times were tough and celebrating with me with each achievement. I love you with all my heart and no words can explain how blessed I am to have you.

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"I can do all things through Him who strengthens me"
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Abstract

Background: Poor balance is a risk factor for injury in adolescent sport including soccer. Despite the rapid growth in female adolescent soccer especially in South Africa, the association between balance and injury in this population has not been fully explored. This study aimed to determine the relationship between injury and balance. Static and dynamic balance was monitored as sway index (SI) and limits of stability direction control (LOSDC).

Objectives: The objectives of this study were to determine the body mass index of adolescent female soccer players; to determine the prevalence of injury in adolescent female soccer players; to determine static balance as revealed by the sway index (SI); to determine dynamic stability as revealed by limits of stability direction control (LOSDC) and to correlate body mass index (BMI) to sway index and limits of stability.

Method: Eighty adolescent female soccer players, between the ages of fourteen and eighteen, were recruited through convenience sampling from schools in the eThekwini district of KwaZulu-Natal. After obtaining informed consent and assent, participants completed questionnaires and were scheduled for the balance and BMI assessments. The objective data for each participant consisted of height, weight, Sway Index (SI) and Limits of Stability Direction Control (LOSDC) readings, measured using a stadiometer, electronic scale and Biodex Biosway Balance System (Biodex Medical Systems Inc., Shirley, New York) respectively. The subjective and objective data were analyzed using SPSS version 21.0 (SPSS Inc. Chicago, Ill, USA). Statistical tests included descriptive statistics using frequency and cross-tabulation. Inferential statistics using t-tests and Pearson's correlations at a significance level of 0.05 was also incorporated. The testing of hypotheses was performed using Fisher's Exact tests for nominal data and ordinal data. A p value of < 0.05 was considered as statistically significant. The statistical analysis also included Odds Ratio calculations.

Results: The mean body mass index of the injured participants was 23.54±3.56 kg/m^2 and the mean body mass index of the uninjured participants was 23.00±4.63. Only 27.5% of the participants sustained an injury. Injured participants performed poorly on average in the SI assessment involving their eyes open when standing on a soft surface. The results were similar for the LOSDC in the overall, right, left, backward-right and backward-left directions. However, there were no significant correlations calculated. Significant relationships existed between BMI and the SI assessments in the injured participants which involved standing on a firm surface with their eyes open (p = 0.05), their eyes closed when also standing on a firm surface (p = 0.05), their eyes open when standing on a soft surface (p = 0.02), and their eyes closed when standing on a soft surface (p = 0.04). A significant relationship also existed between BMI and LOS right direction control (p = 0.02).

Conclusion: This research paper revealed that the body mass index as investigated in this study is similar to other studies involving female adolescents; soccer injury as investigated in this study is similar to other studies involving female adolescents; poor static and dynamic balance is not associated with injury in adolescent female soccer players and lastly, body mass index is linked to the balance of an individual.

Key words: Static balance; Dynamic balance; Injury; Body Mass Index; Stability Index; Limits of Stability.

Table of Contents

List of Appendices

List of Tables

List of Figures

Definitions

Adolescent: An individual between the ages of 10 and 19 years (WHO 2013). According to Barnhart and Barnhart (1989), adolescence can be used interchangeably with the word youth.

Centre of Gravity: 'That point of a body around which its weight is evenly balanced; that point at which the force of gravity acting on the body may be said to be concentrated' (Barnhart and Barnhart 1989a: 329).

Dynamic Balance: Refers to the balance of an individual when dynamically challenged (Hrysomallis, McLaughlin and Goodman 2006: 289). Furthermore, according to Kinzey and Armstrong (1998 cited in Cachupe, Shifflett and Kahanov *et al.* 2001: 98), dynamic balance is associated with the body's preservation of balance when conditions cause the centre of gravity of the individual to move due to muscular activity.

Female: Belonging to the gender that can bear offspring (South African Oxford School Dictionary 2004: 169).

Injury: This particular definition of injury refers to injury received in soccer match play or training that may or may not have required medical or self-treatment and may or may not have prevented the individual from playing.

Prevalence: 'Prevalence is the measure of injuries in a population at a given point in time (point prevalence) and can also be measured over a period of time (period prevalence)' (Friis and Sellers 1999 cited in Mtshali, Mbambo-Kekana and Stewart *et al.* 2009: 164).

Static Balance: Static balance refers to the ability to keep an upright posture and to maintain the centre of gravity within the base of support (Figura, Cama and Capranica *et al.* 1991 cited in Rival, Ceyte and Olivier 2005: 133).

Abbreviations

BMI:	Body Mass Index
COG:	Centre of Gravity
CNS:	Central Nervous System
LOS:	Limits of Stability
MCTSIB:	Modified Clinical Test for Sensory Integration and Balance
SI:	Sway Index
<:	Less Than
>:	Greater Than
≥:	Greater Than or Equal To
***n*:**	Sample Size
EOFS:	Eyes Open Firm Surface
ECFS:	Eyes Closed Firm Surface
EOSS:	Eyes Open Soft Surface
ECSS:	Eyes Closed Soft Surface
OR M-H:	Mantel-Haenszel Common Odds Ratio Estimate
CI:	Confidence Interval
Asymp. Sig:	Asymptotic Significance
No.:	Number of
***p*:**	Probability-value of Statistical Significance
***R*:**	Correlation Coefficient
Vs.:	Versus

Chapter One
Introduction

1.0 Introduction

Female high school soccer in South Africa has gained popularity and grown significantly with more learners participating in the sport (Mtshali, Mbambo-Kekana and Stewart *et al.* 2009: 163). The South African Department of Sports and Recreation (2005: 10), has reported that 38.9% of female learners are motivated to play sport at high school if it forms part of the curriculum. Despite the positive growth in female soccer, Wong and Hong (2005: 474) found that more females incur injuries from playing soccer compared to males.

Soccer involves a high rate of jumping, sprinting, pivoting activity (Emery 2005: 183), cutting movements (Landry, McKean and Hubley-Kozey *et al.* 2009: 375), contact and tackling (Oztekin, Boya and Ozcan *et al.* 2009: 23) in order to get the ball from an opposing player, to keep the ball or to pass the ball. These processes often contribute to the mechanisms of injury (Emery 2005: 183) in soccer. The notion that there is an increased risk of injury in females is possibly due to the perception of a lower skill level or it may be more physiologically based (Emery 2005: 183). Lasalandra (2011) suggests that females are more vulnerable than males to injury because of the differences in their physiology, and body composition. Lewis (2000: 470) emphasizes that healthcare practitioners and coaches involved in screening, training and treating female athletes should have a greater awareness pertaining to the warning signs of impending injury and implement training programmes to improve balance, agility and neuromuscular synchronisation.

The literature confirms that adolescents (over 13 years) who participate in sports are at a greater risk of injury than younger individuals (Lyman, Fleisig and Waterbor *et al*. 2001: 1807). Furthermore, according to Armstrong and Mechelen (2000 cited in Emery 2005: 184), adolescents undergo rapid skeletal growth, which provides greater potential injury risk. Schiff (2007: 371) suggests that research should evaluate risk factors in young developing athletes in order to identify injury prevention strategies.

Risk factors for injury in adolescents participating in sport are of both an intrinsic and extrinsic nature (Emery 2005: 182). These factors are either non-modifiable or potentially modifiable (Emery 2005: 182). Few epidemiological studies have addressed modifiable risk factors for injury in adolescent sport (Emery 2005: 195). According to Emery (2005: 182), potentially modifiable extrinsic risk factors include sports rules, playing time, playing surface, and equipment and potentially modifiable intrinsic risk factors include fitness level, training, flexibility, strength, joint stability, biomechanics, balance, proprioception, psychological and social factors. Emery (2005: 182) mentions that most studies on the relationship between balance and injury only focus on the adult population providing a need for paediatric evaluation. This study will investigate, analyse and attempt to understand balance as a risk factor for injury in female adolescents.

Balance refers to the ability of the Central Nervous System (CNS) to integrate information received from the somatosensory, vestibular, and visual systems (Riemann and Guskiewicz 2000: 49). The input from these systems allows the individual to sense their body position in relation to gravity and their surroundings (Riemann and Guskiewicz 2000: 37). The CNS interprets the information and coordinated neurological signals will be sent to the appropriate muscles for the corrective actions that aid in the maintenance of balance to occur (Kejonen 2002: 22). The centre of gravity (COG) of the individual is therefore maintained. As stated by Barnhart and Barnhart (1989a: 329), the centre of gravity refers to 'that point of a body around which its weight is evenly balanced; that point at which the force of gravity acting on the body may be said to be concentrated'. According to Caraffa, Cerulli and Projetti *et al.* (1996 cited in Emery 2005: 186); Bahr and Lian (1997 cited in Emery 2005: 186) and Wedderkopp, Kaltoft and Lundgaard *et al.* (1999 cited in Emery 2005: 186), balance training with emphasis on the proprioceptive system may decrease the risk of injury in sport, however, there is a scarcity of information in the sporting literature pertaining to the effect of decreased proprioception as a risk factor for injury. There are a number of elements other than the visual, vestibular and somatosensory systems which are integral to an understanding of balance. These elements include postural sway and limits of stability.

Due to the paucity of studies that relate injury prevalence to static and dynamic balance, there is a need to investigate this relationship. The need to investigate this relationship is especially important in adolescents and females due to the structural and physiological peculiarities in this specific population. Essentially, this study aims to determine the relationship between balance and injury in adolescent female soccer players. Injury is subdivided into a number of categories all of which are compared to Biodex Biosway Portable Balance System test results, which includes sway index and limits of stability direction control.

1.1 Aims and Objectives of the Study

The aim of this study was to determine if there is a relationship between injury and balance in female adolescent soccer players.

Objective One: To determine Body Mass Index of adolescent female soccer players.

Objective Two: To determine the prevalence of injury in adolescent female soccer players.

Objective Three: To determine static balance as revealed by the sway index (SI).

Objective Four: To determine dynamic stability as revealed by the limits of stability (LOS).

Objective Five: To correlate body mass index to sway index and limits of stability.

1.2 Flow of the thesis

Chapter One has introduced the topic and provided justification for the study using the literature and anecdotal evidence. The aim, objectives and reasoning behind the study have been outlined.

Chapter One is followed by Chapter Two, the Literature Review. This involves a critical analysis of the available body of literature pertaining to the elements involved in this dissertation. Due to the nature of the topic and the shortage of current information relating to the topic, it was necessary to review literature published as far back as 30 years ago. It also includes information on instruments used to measure dynamic and static balance.

Chapter Three provides an explanation of the research methods and techniques used to achieve the aim and objectives of the study. This involves an outline of the methods, materials and instruments used to structure the design of this research project.

Chapter Four provides the results presented in the form of narratives, tables and figures. A detailed account of the demographic information about the participants is presented first followed by the core data in a form that addresses the aim and objectives.

Chapter Five discusses the results in relation to current and dated literature on the topic presented in the literature review section. Due to the scarcity of literature on this particular topic, reference has been made to dated but related literature.

Chapter Six concludes and shows how the results align to the title, aims and objectives and hypotheses of the study. In addition, a critical review of the limitations of the study is presented. The recommendations relate to aspects in which this study can be strengthened.

Chapter Two
Literature Review

2.0 Introduction

This chapter provides a detailed and in-depth analyses and review of the available body of literature regarding the aforementioned topic of investigation. However, the available literature focused on injuries in adolescents in general since very few publications have investigated soccer injuries in adolescents. Relevant available literature was accessed through a number of sources including the Durban University of Technology library, journal archives and institutional repository, the University of Johannesburg institutional repository, numerous scientific journal databases (viz. Science Direct, Springerlink, Pubmed, Taylor and Francis Online, Wiley Online Library and Google Scholar) and other sources of relevance. All searches included the title of the thesis as keywords. The search for information was not limited by the year of an article and / or journal publication. All accumulated information was analysed and discussed.

2.1 Soccer

Soccer is one of the most popular sports played in the world (Mandelbaum and Putukian 1999: 254). The World Book Encyclopaedia (1989: 544) highlights that soccer is a team sport played with eleven players by two opposing teams and the objective of the game is to kick or nudge the ball through the goalpost beyond the goalkeeper in order to get a point. The ball is permitted to be nudged or kicked with any part of the body except for the arms and hands (World Book Encyclopaedia 1989: 544). Only the goalkeeper in each team is allowed to touch the ball with their arms or hands (World Book Encyclopaedia 1989: 544). Soccer involves a high rate of jumping, sprinting, pivoting activity (Emery 2005: 183), cutting movements (Landry *et al.* 2009: 375), contact, tackling (Oztekin *et al.* 2009: 23), kicking (Barfield, Kirkendall and Yu 2002: 73) and running (Howe 1996: 20) in order to get the ball from an opposing player, to keep the ball or to pass the ball. These processes often contribute to the mechanisms of injury (Emery 2005: 183) in soccer and will be discussed in relation to the common injuries experienced by adolescents later in this review. Frequent mechanisms of injury in soccer include running (Hawkins, Hulse and Wilkinson *et al*. 2001: 45), being tackled (Wong and Hong 2005: 479) and collision with a player (Agel, Todd and Dick *et al.* 2007: 274). When playing soccer an individual needs to stay upright and as stated by Tahboub (2009: 195), staying upright requires coordination of the postural control procedure. This involves processes associated with postural control including contributions from the vestibular, visual, proprioceptive or somatosensory systems (Winter 1995: 194) and the muscles involved in postural stability (Kejonen 2002: 22) in order to keep balance (Horak and Macpherson 1996 cited in Tahboub 2009: 195). Arend (1981 cited in Chew-Bullock, Anderson and Hamel *et al.* 2012: 1616) highlights that balance is important in the performance of numerous skills (such as those mentioned in soccer). Humans have the ability to maintain their balance during a large number of activities (Tahboub 2009: 195) including skilled movements (Gibson and Pick 2000 cited in Chew-Bullock *et al.* 2012: 1615) of which soccer is a clear example, and this ability is impeded during injury.

2.1.1 Youth Soccer

Soccer is very popular among the youth (Steffen, Myklebust and Andersen *et al*. 2008: 1). According to Ward (1987 cited in Schiff 2007: 369), the popularity of soccer in adolescents is due to the perception that soccer is a relatively safe sport. However, regardless of this perception, in a recent study performed in the United States of America (USA) by Fernandez, Yard and Comstock (2007: 643), it was found that soccer accounts for the highest rate of lower-limb injuries in female adolescents, while American football accounts for the highest rate of lower-limb injuries in male adolescents. As discussed in a Canadian health review, it was found that 65% of adolescents participate in some form of physical activity at least 12 times a month as opposed to only 40% of adults (Canada, Culture and Tourism Division 1997 cited in Emery 2005: 180).

2.1.2 Injury Potential

Yde and Nielsen (1990: 52) and Richmond, Kang and Emery (2012: 1), have reported that adolescents are at a greater risk of injury than individuals of a younger age. It is also highlighted by the aforementioned authors that a higher injury rate occurs in older adolescents, especially when they play soccer. Sports injuries in adolescents may be foreseeable and potentially avoidable (MacKay, Scanlan, Olsen *et al.* 2004: 64). As stated by Emery (2005: 180), there is less evidence in the literature pertaining to injury prevention strategies in youth participating in sport as opposed to that in adults.

Emery (2005: 180) suggested that in order to understand injury and its extent in youth sport; one has to consider a number of factors. These factors include injury incidence, the individual at risk and risk factors (Emery 2005: 181). Other important elements to review in addition to the three aforementioned factors include the physiology of the adolescent which includes skeletal maturation (Grady and Goodman 2010: 170), common types of injury (Roach and Maffulli 2003: 60), the pathophysiology of injury (Roach and Maffulli 2003: 59) and injury risk in team versus individual sport as discussed in the study by Theisen, Frisch and Malisoux *et al*. (2013).

2.1.3 Injury Incidence and Prevalence

Injury from sport and recreational activities is the leading cause of morbidity in the adolescent population (Emery 2005: 181). Emery (2005: 194) asserts that sports injury in adolescents may possibly affect the future wellbeing of the population. An investigation into the epidemiology of adolescent sports injury in Alberta Canada revealed that the incidence rate of sports injuries that requires medical attention was highest in adolescent males and females at a rate of 26 injuries per 100 adolescents per year (Mummery, Spence, Vincenten *et al.* 1998: 55). Roach and Maffulli (2003: 58) emphasized that sports involving contact and jumping (such as football or soccer) incur at a much higher rate of injury.

The popularity of soccer in adolescents has lead to a greater participation in the sport and hence a larger number of injuries (Koutures and Gregory 2010: 410). Wong and Hong (2005: 473) selected and reviewed thirty-seven articles pertaining to soccer injuries in both adults and adolescents. Mechanism of injury, parts of the body injured and type of injury were three of the categories selected (Wong and Hong 2005: 473) and results were similar between adults and adolescents. As stated by Wong and Hong (2005: 475), tackle, running and collisions with other players were the most common mechanisms of injury. The knee, ankle, upper leg, groin and hip were the most common parts of the body injured (Wong and Hong 2005: 476). Lastly, sprains, strains, contusions (bruising) and tendonitis were the most common types of injury (Wong and Hong 2005: 477). Despite the extensive findings of Wong and Hong (2005), injuries were not confined to either matches or practice. Wong and Hong (2005: 481) admit that there are differences in matchplay and practice that would need to be further investigated in order to provide strength to their results.

As there is an extremely high incidence of injury in the adolescent population, it is important to analyse the adolescent in terms of their physiological characteristics.

2.1.4 Physiology of the Adolescent

According to Grady and Goodman (2010: 170), it is through an understanding of the unique elements associated with the growing skeleton that one will better comprehend adolescent athletic injury. Physiologically, the skeletal growth of adolescents is of a rapid nature and this affords a greater possibility for injury (Roach and Maffulli 2003: 59) and resultant balance deficit.

In the developing skeleton, the growing bone consists of the growth plate complex which includes the bony epiphysis, the cartilaginous physis and bony diaphysis, and the apophysis (Grady and Goodman 2010: 170). As asserted by Grady and Goodman (2010: 170), the apophysis refers to a cartilaginous outgrowth of the actual bone which forms an area of attachment for various muscles. During the growth process, there is a dividing of the distal aspect of the cartilage while the proximal aspect of the cartilage converts to bone, this process is called endochondral ossification (Grady and Goodman 2010: 170). The area of new bone that has been formed is a lot stiffer than the adjacent cartilage, however it is less compact and structurally fragile in comparison to the surrounding bone (Grady and Goodman 2010: 170). Hoang and Mortazavi (2012: 360) proposed that chronic (over a long period of time (Medline Plus, 2012)) stress placed on the apophysis results in an inflammation of the apophysis which is called apophysitis. Furthermore, sudden violent strain placed on the apophysis often leads to an avulsion fracture of this new bone (Carty 1998: 170). Cutting movements which involve sudden changes in directions (Houck 2003: 548), sprinting (Emery 2005: 183) and tackling (Oztekin *et al.* 2009: 23) can cause avulsion fractures, and because soccer involves repetitive strain, apophysitis can also occur. Furthermore, Grady and Goodman (2010: 170) point out that bone growth stimulates the growth of soft tissue which includes muscle lengthening. It is at the musculotendinous or "muscle tendon" junction that the myocytes or muscle cells are stimulated to lengthen (Grady and Goodman 2010: 170). During rapid growth, the muscle and bone development isn't completely synchronised which results in a loss of flexibility (Grady and Goodman 2010: 170). This change in flexibility can contribute to increased tension on the apophysis and joint changes of biomechanical nature (Grady and Goodman 2010: 170).

Another fundamental element to consider in the adolescent is the effect of hormonal factors on injury. This will be discussed in more detail in this literature review as part of the section on the female athlete. The association between physiological development and injury in the adolescent will be further discussed with a detailed analysis of common sports injuries in the adolescent athlete.

2.1.5 Common Sports Injuries in the Adolescent

The discussion on common sports injuries in the adolescent is structured into eight sections to promote understanding. These sections will include a general section, where contusions; muscle strains and tears; overuse syndrome; stress lesions; apophysitis; chondral and osteochondral lesions; musculotendinous and ligamentous injuries and fractures will be discussed. This will be followed by sections discussing foot and ankle injuries; leg injuries; knee injuries; hip and pelvic injuries; back injuries; elbow injuries and shoulder injuries respectively. In a study performed by Hawkins *et al*. (2001: 46) on soccer injuries, eighty-seven percent of the injuries studied were pertained to the lower extremities.

2.1.5.1 General Injury

2.1.5.1.1 Contusion

As discussed by LaBella (2007: 31), contusions (or bruising) are a result of direct blunt trauma to a muscle or to soft tissue and commonly occur in sports that involve collisions including soccer. Most contusions are not serious; however, contusions of the quadricep muscles are the most disabling (LaBella 2007: 31). Tenderness, swelling, ecchymosis (or bleeding below the skin) and a reduced and painful range of motion form part of the clinical presentation of a contusion (LaBella 2007: 31). Kary (2010: 28) further highlights that haematomas can develop after a contusion. When there is a contusion with the development of an intramuscular haematoma a complication known as myositis ossificans can result (LaBella 2007: 31). Myositis ossificans is a benign proliferation of bone and cartilage that ensues within the muscle about three weeks after trauma to the muscle (LaBella 2007: 31). According to LaBella (2007: 31), Myositis ossificans can have a negative effect on muscle functioning and flexibility and slows down recovery.

2.1.5.1.2 Muscle Strains and Tears

Muscle strains occur as a result of an abrupt forceful alteration in the length of a muscle-tendon unit, which results in stretching or tearing of the fibres (LaBella 2007: 32). As emphasized by LaBella (2007: 32), this usually occurs at the muscle-tendon junction. Due to the unsynchronised bone and muscle growth patterns during adolescence as discussed by Grady and Goodman (2010: 170) in a study performed at the Sports Medicine and Performance Centre at the

Children's Hospital of Philadelphia, adolescents are vulnerable to a loss of flexibility, resultant tension on the apophysis leading to joint biomechanical change, and hence greater strain on associated muscle. LaBella (2007: 32) has classified muscle strains as being mild, moderate or severe. Mild strains are stretch injuries that don't affect muscle function, including strength and range of motion; moderate strains involve a slight tear of the muscle and include a loss of strength, range of motion of the muscle, and ecchymosis and swelling to an extent; severe strains involve a complete tearing of the muscle, a complete loss of normal muscle functioning and major haemorrhage (LaBella 2007: 32). According to LaBella (2007: 32), athletes involved in sports that include sprinting, jumping, leaping or kicking (such as soccer) are most vulnerable to muscle strains. Running at high and medium pace involves the activation of similar muscles at a higher and lower intensity of contraction respectively (Yokozawa, Fujii and Ae 2007: 3471). As highlighted by Yokozawa, Fujii and Ae (2007: 3471), the iliopsoas muscle has the highest average activation during running followed by the rectus femoris muscle and adductor muscle group. According to Steyn (2004), during kicking action hamstring strains are common.

2.1.5.1.3 Overuse Injury

Roach and Maffulli (2003: 59) indicate that overuse injury in the adolescent population has become more apparent. Overuse injury includes stress fractures, tendinopathies or bursitis (Roach and Maffulli 2003: 59). Essentially, as emphasized by Carty (1998: 164), many lesions in the adolescent athlete occur due to overuse especially when there is not enough time for recovery from previous trauma. According to Roach and Maffulli (2003: 59), when atypical loads are employed in a specific direction or in a frequency that is greater than the pace of adaptive changes of the tissues, overuse injury can occur. This happens at the pinnacle of the growth rate (Roach and Maffulli 2003: 59). Hoang and Mortazavi (2012: 374) emphasize that when bone growth is faster than the stretching ability of the muscle (such as during the adolescent growth spurt), injuries of this nature may occur.

Risk factors for overuse injury are of both intrinsic and extrinsic nature (DiFiori 1999: 2). Intrinsic factors include growth (which refers to an increased vulnerability of developing cartilage to recurring stress, inflexibility and muscular imbalance), previous injury, insufficient conditioning, anatomic malalignment, menstrual dysfunction and psychological factors (DiFiori 1999: 2). According to DiFiori (1999: 2), extrinsic factors comprise inappropriate training advancement, inadequate respite, footwear, incorrect technique, playing surface and pressure from adults and peers.

DiFiori (1999: 3) asserts that growth factors are associated with two important elements. These elements include the susceptibility of growth cartilage to repetitive stress and secondly the quick transformation in the lengths of long bones in relation to their muscle-tendon units (DiFiori 1999: 3). When bones lengthen more rapidly than their associated muscle tendon units, tightness of the muscle, inflexibility and muscle imbalance results (DiFiori 1999: 3).

According to DiFiori (1999: 3), individuals with a history of injury may have recurring errors in training/technique that have not been corrected and often their past injuries have not been properly treated or even ignored. Furthermore, in terms of conditioning, unconditioned individuals will be unfit, have poor proprioceptive skills and weak inflexible musculoskeletal structures (DiFiori 1999: 4). Anatomic malalignment abnormalities linked with overuse injury consist of pes planus, pes cavus, hyperpronation, tibial torsion, patellofemoral malalignment, femoral anteversion and leg-length discrepancy (DiFiori, 1999: 3). Lastly, menstrual dysfunction is often related to decreased bone mineral density leading to injury (Lebrun 2006: 167), and psychological factors such as pressure from peers or adults may have an effect on motivation and hence affect the individual's capability to concentrate on safety and conditioning (DiFiori 1999: 4). As proposed by DiFiori (1999: 4), inappropriate training progression refers to changes in training frequency, intensity and rest periods. Footwear or equipment that is not the correct size may lead to biomechanical abnormalities and resultant dysfunction of the lower extremities which will increase the likelihood of injury (DiFiori 1999: 4). The playing surface that the individual uses may also have an effect on lower extremity biomechanics (DiFiori 1999: 4). Lastly, poor technique may lead to overuse injury if not corrected (DiFiori 1999: 4).

2.1.5.1.4 Stress Lesions

The discussion on stress lesions will include stress fractures, compartment syndromes, shin splints and medial tibial stress syndrome (Carty 1998: 164).

Philipson and Parker (2009:137) point out that stress fractures occur when there is repetitive stress exerted on the bone just below the stress required to fracture the bone at a single stress. Furthermore, Daffner and Pavlov (1992: 245) propose that stress fractures can occur due to protracted muscular stress on a bone that has not adapted to that stress.

Mandelbaum and Putukian (1999: 257) state that sports that commonly result in stress fractures include soccer. Common sites of stress fractures include: the middle third of the tibia of the lower leg; the distal third of the fibula of the lower leg; the shafts of the metatarsals of the foot; the centre of the navicular of the foot; the anterior cortex of the femur of the upper leg; the first rib; the pars interarticularis of the spine; the pubic ramus of the pelvis and the physis of the wrist (Carty 1998: 164). Carty (1998: 164) states that stress fractures of the foot bones are commonly seen in military recruits, dancers and runners – soccer would obviously be included as it involves a fair amount of running. According to LaBella (2007: 40), a Salter-Harris 1 stress fracture of the distal fibula is the most frequent acute (sudden onset (Medline Plus, 2012)) injury of the foot and ankle in the skeletally immature athlete. Raissaki, Apostolaki and Karantanas (2007: 90) assert that fractures in the adolescent usually happen as a result of a direct knock or a twisting injury which can occur during soccer collisions and tackles. The adolescent is particularly vulnerable due to the weakness of the developing bone (Raissaki, Apostolaki and Karantanas 2007: 90).

Perron, Brady and Keats (2001: 413) highlight that a “compartment” in the case of compartment syndrome refers to body tissue that is enclosed by fascia forming a closed space and it usually involves muscles enclosed by sheaths of fascia. Compartment syndrome occurs when there is a compression of the compartment or as a result of an increased volume within the compartment such as during inflammation (Perron, Brady and Keats 2001: 413). When there is increased internal pressure within the muscle compartment which does not return to normal post sports training, this may lead to the eventual development of ischaemic necrosis (or tissue death within the muscle due to decreased oxygenated blood supply) (Carty 1998: 164). Compartment syndrome ordinarily occurs after leg injury including fractures of the tibia diaphysis and injury to the muscle (McQueen, Gaston and Court-Brown 2000: 201) which can happen during soccer collisions. As proposed by McQueen, Gaston and Court-Brown (2000: 201), compartment syndrome typically affects males between the ages of fourteen and nineteen as opposed to females where it is much less common.

Shin splints occur as a result of an enthesopathy of the anterior tibial cortex (Carty 1998: 164). As explained in the Oxford Handbook of Clinical Medicine (Longmore, Wilkinson and Turmezei *et al.* 2007: 537), an enthesitis refers to inflammation at the site of the insertion of a tendon or ligament into bone, thus the term enthesopathy is any pathological condition associated with this site. According to Anderson (2005: 134), during activities that involve running (such as soccer), the muscles of the lower extremity act as shock absorbers and provide stability. As the duration of participation in the specific activity increases, greater stress will be placed on the leg muscles which in turn will increase the shock absorption and stability requirements (Anderson 2005: 134). As pointed out by Anderson (2005: 134), as a result of this increased demand there will be a pulling of the anterior lower leg muscles on their attachment to the tibial bone leading to pain.

According to Carty (1998: 164), medial tibial syndrome is expressed as a pain that is experienced at the medial border of the lower third of the tibia which is caused by exercise. This discomfort takes several hours or days to be relieved (Carty 1998: 164). Anderson (2005: 134) highlights that medial tibial syndrome is associated with overload and can be related to the shoes of the individual, the surface the individual uses for their activity and the amount of activity. This pain will be exacerbated when activity takes place on hard surfaces (Anderson 2005: 134).

These last three conditions may overlap and may occur or co-exist with stress fractures (Carty 1998: 164).

2.1.5.1.5 Apophysitis

Apophyseal injuries are exclusive to the undeveloped skeleton (Carty 1998: 167). An Apophysis consists of cartilage cells and hence is more fragile than the muscle tendon unit attached to it – which consists of much stronger connective tissue (LaBella 2007: 37). During adolescence prior to the fusion of the apophysis to the bone, sudden violent strain placed on the apophysis often leads to an avulsion fracture of this new bone (Carty 1998: 170) which is known as an acute (Carty 1998: 167) avulsion fracture. Avulsion can simply be understood as a “tearing away” (Fowler and Fowler, 1951: 79) of something – in this case a muscle from a bone.

Anderson (2005: 129) points out that sports such as soccer which involve jumping, landing, accelerating, decelerating, stopping and an altering of direction can lead to an avulsion fracture. Yokozawa, Fujii and Ae (2007: 3471) assert that the rectus femoris and hamstrings are important muscles activated during high speed as well as medium velocity running. Rossi and Dragoni (2001: 131) highlight that during an intense kick of the ball there is a sudden flexion of the hip and extension of the knee which involves contractions of the iliopsoas and rectus femoris respectively. This in turn can lead to avulsion fractures of the insertion sites of these muscles including the lesser trochanter of the femur and the anterior inferior iliac spine. Rossi and Dragoni (2001: 131) further propose that the anterior superior iliac spine is also a common site of avulsion injury during kicking movements. Sites of avulsion are listed in Table 2.1 as seen below.

Table 2.1 Sites of Avulsion (Carty 1998: 171)

Insertion Site:	**Muscle:**
Ischial tuberosity	Hamstring
Anterior superior iliac spine	Sartorius and tensor fascia lata
Anterior inferior iliac spine	Rectus femoris
Lesser trochanter	Ilio psoas
Iliac crest	Abdominal muscles
Pubis	Hip abductors
Superior pole of patella	Quadriceps
Inferior pole of patella	Patella tendon
Tibial spines	Cruciate ligaments
Tibial tuberosity	Ligamentum patellae
Medial femoral condyle	Adductor magnus
Calcaneal apophysis	Tendo Achilles
Medial humeral epicondyle	Flexor pronator muscles
Olecranon	Triceps

Chronic apophysitis occurs as a result of recurrent traction on the apophysis and affects the shoulder, elbow, knee and heel (Carty 1998: 168). Chronic apophysitis has been given a number of names based on the sport in which the individual participated – and this includes tennis elbow, little league elbow, swimmer's shoulder and jumper's knee (Carty 1998: 168). According to Peck (1995 cited in Carty 1998: 168), chronic apophysitis occurs as a result of inflammation at the area where the tendon inserts into a bony prominence. Furthermore, according to Anderson (2005: 153) calcaneal apophysitis is common in soccer players as it involves running and often the shoes used do not have enough protection for the calcaneal apophysis. Carty (1998 168) mentions that a number of eponyms have been given to chronic apophyseal lesions, namely: Osgood Schlatter's disease, Sever's disease and Sinding-Larson-Johansson syndrome.

2.1.5.1.6 Chondral and Osteochondral Lesions

The discussion on chondral and osteochondral lesions will include osteochondritis dissecans and retropatellar pain (Carty 1998: 168).

Carty (1998: 168) asserts that osteochondritis dissecans (OD) is an impaction injury with resultant subchondral fissuring and the separation of a small portion of the bone from the adjacent cartilage. In adolescents OD usually occurs up to the age of fifteen years (Pill, Ganley and Flynn *et al.* 2001: 25). Collisions and tackles during soccer are important mechanisms of potential injury which could lead to OD. The knee is frequently involved with the lateral aspect of the medial femoral condyle being a commonly involved site (Pill *et al.* 2001: 25). Other common sites of injury include the talus, the capitellum and the heads of the metatarsals (Carty 1998: 168). According to Grady and Goodman (2010: 178), OD is possibly caused by repetitive microtrauma, acute trauma, ischaemia, endocrine factors and genetic factors. Clinically the patient may complain of chronic pain especially during exercise and, there may be joint locking as a result of loose bone fragments (Carty 1998: 168). Carty (1998: 168) further mentions that OD often occurs along with bone contusions and meniscal injury. In advanced OD the subchondral bone and adjacent cartilage may begin to fracture (Grady and Goodman 2010: 178).

According to Carty (1998: 169), retropatellar pain is a common clinical presentation in the youth – especially girls that participate in sport. The two main lesions leading to retropatellar pain include patellar maltracking and chondromalacia patellae (Carty 1998: 169).

Patellar maltracking is related to a reduced depth of the femoral intercondylar area – which results in a chronic subluxation (or partial dislocation) of the patella (Carty 1998: 169). As proposed by Boon, Colledge and Walker *et al.* (2006: 1081), chondromalacia patellae is a self-limiting condition and involves non-progressive fibrillation of the retro-patella cartilage.

2.1.5.1.7 Musculotendinous and Ligamentous Injury

Musculotendinous injuries may occur as a result of overstretching a muscle leading to a tear or if chronic as a result of repetitive strain (Carty 1998: 170). As discussed previously, an avulsion fracture at the apophysis in an adolescent may occur due to an abrupt severe powerful muscular contraction. According to Carty

(1998: 170), musculotendinous injuries occur most frequently in the lower limb, the location and occurrence of which depends on the muscle group and the sport in which the individual is involved.

Tears of the cruciate ligament occur as a result of sudden hyperextension and twisting of the knee, and are much less common in adolescents as a result of a greater ligament laxity (Carty 1998: 170). The same mechanism of injury that leads to a cruciate ligament tear in adults will result in an avulsion injury of the tibial spine in adolescents (Carty 1998: 170). However, despite this, anterior cruciate ligament (ACL) injuries are becoming more common in the adolescent and pediatric population (AlHarby 2010: 72). Anderson (2005: 137) indicates that the ACL provides support to the knee especially when the knee is extended. A soccer player who is tackled while their knee is in an extended position can commonly tear their ACL (Anderson 2005: 137).

2.1.5.1.8 Fractures

Transphyseal and physeal fractures of the distal femur occur commonly in contact sports (such as soccer) when the leg of the individual being tackled is held firm while the rest of the body continues to move with momentum (Smith and Tao 1995 cited in Carty 1998: 173). Sports that involve jumping and twisting activity may result in tibial plateau impact injuries such as fractures of the tibial plateau (Carty 1998: 173). According to Carty (1998: 173), patellar fractures have an increased incidence in adolescents participating in sports and occur as a result of torsional movement of the knee. Fractures of the patellar include transverse fractures – as a result of direct trauma, and sleeve fractures – as a result of a sudden twisting motion (Carty 1998: 173). The adolescent may also present with haemarthrosis (bleeding within the joint) (Carty 1998: 173).

2.1.5.2 Foot and Ankle Injury

According to Grady and Goodman (2010: 170), acute and chronic heel and ankle pain are frequent musculoskeletal grievances in the adolescents who play soccer.

In this section the anatomy of the foot and ankle; normal range of motion and gait; and foot and ankle pain in relation to the growth process will be discussed. The discussion will also include foot and ankle injuries in the adolescent.

2.1.5.2.1 Anatomy of the Foot and Ankle

There are three main joints that collaborate in order to promote smooth foot and ankle movement (Grady and Goodman 2010: 171). These three major joints include the ankle joint; the subtalar joint; and the joints involved in abduction and adduction of the foot (Grady and Goodman 2010: 171).

The ankle joint consists of the tibia, fibula and talus and it permits dorsiflexion (such as when standing on one's heels) and plantarflexion (such as when standing on one's toes) predominantly in the sagittal plane (or up and down) (Grady and Goodman 2010: 171). The subtalar joint consists of the talus and calcaneus and it allows for movement predominantly in the coronal plane (or side to side) (Grady and Goodman 2010: 171). The transverse tarsal joints; the calcaneo-cuboid joint; and the talo-navicular joint aid in foot abduction (moving the foot away from the midline of the body) and foot adduction (moving the foot towards the midline of the body) (Grady and Goodman 2010: 171).

2.1.5.2.2 Range, Motion and Gait of the Foot and Ankle

Grady and Goodman (2010: 171) stated that the standard range of motion of the ankle is approximately 40 degrees of plantarflexion and 10-20 degrees of dorsiflexion. Howe (1996: 20) asserts that the foot and ankle have an important role to play during running, kicking and jumping activity in soccer.

Running is divided into two stages including swing and support (Howe 1996: 20). The swing stage starts at the point when the foot leaves the ground to the point when the foot touches the ground once again (Howe 1996: 20). The support stage starts at the point when the foot touches the ground to the point when the foot leaves the ground once again (Howe 1996: 20). When the foot leaves the ground the ankle is initially plantarflexed after which it starts to dorsiflex, once the foot touches the ground again at the end of the swing stage or the start of the support stage the ankle is dorsiflexed and slightly inverted (Howe 1996: 20). However, as proposed by Howe (1996: 20), the ankle is more plantarflexed when an individual runs with the ball. The foot and ankle are able to absorb and transfer forces through the various stages of the gait-cycle as a result of foot pronation and supination (Grady and Goodman 2010: 172). Pronation of the foot occurs when the foot touches the ground during walking, and supination of the foot occurs when the foot leaves the ground (Grady and Goodman 2010: 172). According to Grady and Goodman (2010: 172), during normal walking, slight biomechanical abnormalities do not generally cause any problems of functional nature. However, Grady and Goodman (2010: 172) mention that during running, the ground contact forces related to the feet contacting the ground are increased considerably. Therefore, a slight biomechanical abnormality during running can lead to excessive pressure on other parts and ultimately functional problems resulting in injury (Grady and Goodman, 2010: 172).

Before kicking the ball the ankle (of the kicking foot) is slightly dorsiflexed (Howe 1996: 21). Once the foot strikes the ball the position of the ankle depends on what part of the foot strikes the ball (Howe 1996: 21). In non-professional soccer players it has been found that the contact point is closer to the toes as opposed to contact higher up the foot in professionals. Hay (1996 cited in Barfield, Kirkendall and Yu 2002: 73) state that when the foot contacts the ball the ankle is firmly plantarflexed.

Howe (1996: 22) point out that when an individual jumps (such as attempting to head the ball in soccer) there is initially a dorsiflexion of the ankles followed by an intense contraction of the muscles promoting plantarflexion of the ankles in order to propel the individual as high as possible into the air. Once the individual returns to the ground the ankles are again dorsiflexed (Howe 1996: 22).

2.1.5.2.3 Pain in Relation to the Growth Process

According to Grady and Goodman (2010: 172), the clinical significance of delayed muscle development in relation to bone development is evident in the functioning of the gastrocnemius muscle. The gastrocnemius, soleus and plantaris muscles share a common distal tendon – this is known as the Achilles tendon (Grady and Goodman 2010: 172). The muscle origin of the soleus is the proximal tibia – thus the soleus only crosses over the ankle joint (Grady and Goodman 2010: 172). The gastrocnemius muscle originates at the distal femur – thus it crosses over both the knee and the ankle joint (Grady and Goodman 2010: 172). During adolescent growth, tightening of the gastrocnemius muscle can restrict ankle dorsiflexion to zero degrees during knee extension (Grady and Goodman 2010: 172). As a result, the subtalar and the transverse tarsal joints will make up for the lack of dorsiflexion – the subtalar joint will markedly evert, and the transverse tarsal joint will markedly abduct (Grady and Goodman 2010: 172). This will result in greater stress being placed on the medial arch of the foot and a “pinching” of the anterior lateral ankle joint (Grady and Goodman 2010: 172). Clinically, the individual may present with extreme pronation (flat foot), anterior ankle pain (impingement), and medial foot pain (plantar fasciitis) (Grady and Goodman 2010: 172).

In the developing skeleton the apophysis is weaker in terms of structure in comparison to the adjacent ligaments and tendons (Grady and Goodman 2010: 172). When there is excessive traction of repetitive nature on the calcaneus as a result of a tight gastrocnemius muscle/Achilles tendon, irritation of the calcaneal apophysis can occur (Sever’s disease) (Grady and Goodman 2010: 172). This may result in Achilles tendonitis if the irritation continues (Grady and Goodman 2010: 172). If the apophysis is closed ankle impingement (anterior-lateral) and plantar fasciitis may occur (Grady and Goodman 2010: 172). Tarsal Coalition often impersonates Sever’s disease (Grady and Goodman 2010: 172). This rare condition occurs as a result of abnormal cartilaginous or fibrous connections between any of the tarsal bones (Grady and Goodman 2010: 172). According to Grady and Goodman (2010: 172), the cartilaginous connections often ossify and the fibrous connections can become tauter – which will interfere with normal joint range of motion. As a result, excessive stress will be exerted on other joints especially during activities involving running (Grady and Goodman 2010: 172).

As proposed by LaBella (2007: 32), ankle sprains form twenty-eight percent of all sports injuries and sportsmen/women of fifteen to nineteen years of age are most commonly injured. Ankle sprains are common in sports involving running, jumping and turning (Yeung, Chan and So *et al.* 1994: 112). LaBella (2007: 32) further mentions that eighty-five percent of all ankle sprains are lateral. As highlighted by LaBella (2007: 32), the most common mechanism of injury for an ankle sprain is extreme inversion of an ankle that is plantarflexed. The anterior talofibular ligament of the ankle is the most vulnerable ligament of the foot/ankle to injury and thus is most commonly injured (LaBella 2007: 32). Clinically, the individual will experience pain, swelling and bruising after injury onset (LaBella 2007: 32). If an inversion ankle sprain is experienced in a skeletally immature individual such as an adolescent, radiographic imaging is highly recommended (LaBella 2007: 32). The reason for radiographic imaging in this age group is because the distal fibular physis is weaker than the adjacent ligaments – so there is a higher likelihood of a physeal fracture as opposed to a ligament sprain (LaBella 2007: 33). According to Braun (1999: 146), after an ankle sprain, there is a very large chance of re-injury. Braun (1999: 148) asserts that the completion of a supervised rehabilitation programme including strapping, proprioception training and strength training have been shown to be very effective in preventing reinjury.

As indicated by LaBella (2007: 32), syndesmosis ankle sprains and eversion (or outward turning (Seeley, Stephens and Tate 1998: 1030) ankle sprains do occur but are a lot less common than inversion (inward turning (Seeley, Stephens and Tate 1998: 1036) ankle sprains. Syndesmosis sprains are also known as “high” ankle sprains as the injury is above the ankle joint (LaBella 2007: 34). According to LaBella (2007: 34), syndesmosis ankle sprains happen due to excessive external rotation of the dorsiflexed ankle. Eversion ankle sprains are associated with excessive eversion of the ankle – typically from a fall, leading to injury of the deltoid ligament of the affected ankle (LaBella 2007: 34).

2.1.5.3 Leg Injury

According to Anderson (2005: 134) overtraining or repetitive mechanical loading intensifies the possibility of stress fractures. In the lower limb stress fractures of the tibia are common (Anderson 2005: 135). In adolescents stress fractures occur due to the susceptibility of the developing musculoskeletal system to injury especially at the growth plate (Kerssemakers, Fotiadou and de Jonge *et al.* 2009: 471). Tibial eminence avulsion fractures have become more common in adolescents due to an increased participation in sports (LaBella 2007: 38). The mechanism of injury of a tibial eminence avulsion fracture is hyperextension of the knee with or without genu-valgus or rotational stress (LaBella 2007: 38). Furthermore, Roach and Maffulli (2003: 62) highlighted that overtraining also provides a risk for the development of compartment syndrome (2.1.5.1.3. above).

2.1.5.4 Knee Injury

Anterior knee pain is a frequent musculoskeletal grievance in the adolescent sportsman/sportswoman (Grady and Goodman 2010: 175). In a study performed by Phillips and Coetsee (2007: 62), it was found that the peak incidence of anterior knee pain was found in twelve to thirteen year old females and fourteen to fifteen year old males. Phillips and Coetsee (2007: 62) indicated that these ages are associated with the adolescent growth spurt. Hence, the aetiology of anterior knee pain is commonly linked to the physical development of the individual (Grady and Goodman 2010: 175). Injuries can be of acute or chronic nature – acute injuries include contusions, fractures, sprains of ligaments, muscular strains and cartilaginous injury (Grady and Goodman 2010: 175). According to Grady and Goodman (2010: 175), chronic or sub-acute knee pain is usually at the anterior aspect of the knee.

2.1.5.4.1 The Knee

During running when the foot leaves the ground the knee is initially extended (the leg is straightened) after which it starts to flex (the leg is bent) (Howe 1996: 20).

The knee will then start to extend once more just before the foot touches the ground again (Howe 1996: 20). Howe (1996: 22) proposes that when an individual kicks a soccer ball the knee is flexed just before kicking the ball and from the moment the foot touches the ball the quadricep muscles quickly extend the knee. When an individual jumps in order to head a ball, just before the feet leave the ground the knees will flex which results in the knee acting almost like a spring propelling the individual upwards (Howe 1996: 22).

Anatomically, the knee joint complex consists of two joints – the tibio-femoral joint and the patello-femoral joint (Grady and Goodman 2010: 176). According to Grady and Goodman (2010: 176), the knee is a hinge joint and it allows for movement predominantly in the sagittal plane from zero degrees in extension (and further if increased laxity) to one hundred and forty degrees of flexion. The patella tracks (or moves) between the medial and lateral femoral condyle in the trochlear groove and it does not play a role in knee joint motion (Grady and Goodman 2010: 176). The fibula functions as an attachment area for muscles, tendons and ligaments that assist in stabilizing the knee joint (Grady and Goodman 2010: 176). Grady and Goodman (2010: 176) indicated that the stability of the tibio-femoral joint is sustained by forces of both static and dynamic nature. The static forces include the collateral and cruciate ligaments (Grady and Goodman 2010: 176). The dynamic forces include the muscles that cross over the knee joint such as the hamstrings, gastrocnemius, quadriceps/patella tendon and the iliotibial band (Grady and Goodman 2010: 176). These muscles assist with stability – especially against torsional or rotational forces (Grady and Goodman 2010: 176). According to Grady and Goodman (2010: 176), the patello-femoral joint is less steady than the tibiofemoral joint. The under-surface of the patella articulates with the trochlear groove (Grady and Goodman 2010: 176). When the knee goes into a valgus or outward directed position, the patella has a propensity to track laterally (or outwards) – this is significant in the mechanism of injury in patello-femoral pain syndrome (Grady and Goodman 2010: 176).

As highlighted by Grady and Goodman (2010: 176), knee valgus position and the Q-angle are fundamental in the comprehension of the biomechanics of abnormal knee motion. Knee valgus position and the Q-angle will be discussed later in this literature review as a part of the section on the analysis of the female physiology.

2.1.5.4.2 Traction Apophysitis Injuries of the Knee

During the adolescent growth spurt, the soft tissue growth from the quadriceps-patella tendon complex is slower than the development of the femur (Grady and Goodman 2010: 176). This causes a transitory loss of flexibility which will put stress on the distal apophyseal attachment areas of the quadriceps muscle group (Grady and Goodman 2010: 176). According to Grady and Goodman (2010: 176), Sinding-Larson-Johansson (SLJ) disease is associated with traction apophysitis at the inferior pole of the patella. Osgood-Schlatter disease (OSD) is associated with traction apophysitis at the anterior tibial tubercle (Grady and Goodman 2010: 176). Clinically, individuals with SLJ and OSD experience anterior knee pain in activities involving running, jumping, climbing, squatting and kneeling (Grady and Goodman 2010: 176). But, Grady and Goodman (2010: 176) assert that these two conditions are more common in young males.

2.1.5.4.3 Patellofemoral Pain Syndrome

According to Grady and Goodman (2010: 177), patellofemoral pain syndrome (PFPS) is a term used to depict anterior knee pain around the patella with an unknown pathology. Examples include patellar tendonitis, SLJ and OSD (Grady and Goodman 2010: 177). Female adolescents suffer from PFPS two to ten times more than male adolescents (Myer, Ford and Barber Foss *et al.* 2010: 2). As pointed out by Grady and Goodman (2010: 177), it is most likely that PFPS is due to an increase in the Q angle or as a result of hamstring, gastrocnemius or hip adductor tightness.

2.1.5.4.4 Anterior Cruciate Ligament Injury

Anterior cruciate ligament (ACL) sprains of the knee transpire in sports such as basketball, American football, volleyball and soccer (LaBella 2007: 34). According to Boden, Griffin and Garrett Jr (2000: 8) ACL injuries occur as a result of jumping, running and cutting movements such as during soccer. ACL injuries occur due to excessive internal rotation of the femur with the knee under valgus stress and the foot in a fixed position (Ford, Meyer and Toms *et al.* 2005 cited in Mtshali *et al.* 2009: 166; LaBella 2007: 34). ACL injuries can also be caused by hyperextension of the knee (LaBella 2007: 34).

According to LaBella (2007: 34), ACL injuries rarely occur prior to eleven years of age; however, the incidence of ACL injury amplifies throughout adolescence. According to Boden, Griffin and Garrett Jr (2000: 2) females are up to eight times more prone to injure their ACL than males. The reasons for this gender difference include the effect of Oestrogen on ligament laxity, females having a less stable alignment of the lower extremities than males, a greater strength imbalance than males (Hewett, Meyer and Ford 2005 cited in LaBella 2007: 34) and poor neuromuscular control during landing and cutting movements (LaBella 2007: 34) which occur in soccer.

Roach and Maffulli (2003: 61) also stated that the imbalance between muscle strength, ligament strength and epiphyseal strength in skeletally immature individuals may in some cases lead to an avulsion of the ACL.

2.1.5.4.5 Medial Collateral Ligament Injury

Sprains of the medial collateral ligament (MCL) of the knee often co-exist with ACL injuries or can occur in isolation (LaBella 2007: 35). According to LaBella (2007: 35), the mechanism of injury of a MCL sprain is valgus stress and/or external rotation of the tibia on a fixed foot (i.e. an inward directed force to the knee while there is an outward twisting of the lower leg while the foot remains fixed in the same position on the ground), and is most likely to be caused by a collision with another player. In adolescents who have suffered from a possible MCL sprain, a radiograph should always be performed to rule out a physeal fracture (LaBella 2007: 35).

2.1.5.4.6 Posterior Cruciate Ligament Injury

According to LaBella (2007: 36), posterior cruciate ligament (PCL) injuries can occur as an isolated injury or can occur along with injuries to the postero-lateral area of the knee. According to Anderson (2005: 138) PCL injuries occur as a result of falling on a flexed knee with forces exerted posteriorly on the tibia of the lower leg. PCL tears are seldom seen in adolescents – avulsion fractures are more common (Erickson and Schmale 2003 cited in LaBella 2007: 36).

2.1.5.4.7 Patella Injury

According to LaBella (2007: 36), acute patella dislocations are common in adolescent sportsmen/sportswomen from ten to seventeen years of age. LaBella (2007: 36) proposed that the mechanism of injury of a patella dislocation involves an abrupt internal rotation of the femur and/or valgus stress on the knee while the foot is fixed (i.e. a sudden inward directed force to the knee while there is an inward twisting of the upper leg while the foot remains fixed in the same position on the ground), resulting in a lateral displacement of the patella. The individual will experience a popping or tearing feeling and bleeding within the knee joint area (haemarthrosis) will develop within a few hours (LaBella 2007: 36). Ninety percent of patella dislocations will be spontaneously reduced with active extension of the knee (LaBella 2007: 36). Up to seventy-two percent of patella dislocations of acute nature result in osteochondral or chondral fractures of the patella and/or femur (Stanitski and Paletta 1998 cited in LaBella 2007: 36). According to Anderson (2005: 143), patella dislocations can occur again irrespective of previous management.

Jumper's knee is a condition that occurs in younger athletes who are involved in kicking and jumping sports (like soccer) (Carty 1998: 171). These athletes may develop some pain in the region of the inferior pole of the patella as a result of chronic inflammation (Carty 1998: 171). This chronic inflammation may lead to ossification of the patella and resultant downward lengthening of the inferior pole of the patella resulting in a traction spur (Carty 1998: 171). The atypical patella tendon will also be thickened (Carty 1998: 171). Furthermore, according to Carty (1998: 171), lesions at the inferior pole of the patella, the superior pole of the patella at the quadriceps insertion and the anterior tibial tuberosity often co-exist.

2.1.5.5 Hip and Pelvic Injury

According to Grady and Goodman (2010: 180), musculoskeletal grievances of the hip and pelvis are frequent in middle and late adolescence. During the maturation process the iliac crest apophysis starts to ossify and has a greater possibility of being injured (Grady and Goodman 2010: 180). Pain along the iliac crest is a regular complaint in sports such as soccer, baseball, tennis and lacrosse as these sports involve core rotational movements (Grady and Goodman 2010: 180). An example of a core rotational movement in soccer includes hip rotation prior to the kicking of the ball (Lees 1996: 125).

Apophyses are secondary ossification centres that develop during adolescence (LaBella 2007: 37 and Grady and Goodman 2010: 181). These secondary ossification centres serve as attachment sites for muscles involved in stabilization of the core and hip motion control (Grady and Goodman 2010: 181). According to Grady and Goodman (2010: 181), clinically important areas include the iliac crest, the anterior superior iliac spine, the anterior inferior iliac spine and the ischial tuberosity. Furthermore, secondary ossification centres of the proximal femur include the greater and lesser trochanter (Grady and Goodman 2010: 181). The iliac crest functions as an attachment area for core stabilization muscles and the hip abductors (Grady and Goodman 2010: 181). The core stabilization muscles include the abdominal obliques, and the hip abductors include the gluteus medius and minimus (Grady and Goodman 2010: 181). The anterior superior iliac spine functions as the attachment area for the sartorius muscle, the anterior inferior iliac spine functions as the attachment area for the rectus femoris, and the lesser trochanter of the femur functions as the attachment area for the iliopsoas (Grady and Goodman 2010: 181). The Sartorius, the rectus femoris and the iliopsoas are the primary hip flexor muscles (Grady and Goodman 2010: 181). According to Grady and Goodman (2010: 181), the ischial tuberosity functions as the attachment area for the hamstring muscles – and it combines with the gluteus maximus to produce hip extension.

2.1.5.5.1 Trochanteric Bursitis

According to Grady and Goodman (2010: 181), some athletes complain of a “snapping” sensation at the lateral aspect of the hip during running. This sensation normally occurs at some stage during the adolescent growth spurt when there is a transformation in the shape of the pelvis and reduced flexibility of the iliotibial band (IT band) (Grady and Goodman 2010: 181). This causes the tensor fascia lata/IT band to rub over the greater trochanter of the femur (Grady and Goodman 2010: 181). Greater trochanteric bursitis results when excessive rubbing irritates the bursa sac separating the greater trochanter and the IT band/gluteus medius muscle (Grady and Goodman 2010: 181).

2.1.5.5.2 Avulsion Injuries of the Hip

The secondary ossification centres of the hip/pelvic area are also called apophyses (LaBella 2007: 37). As stated by LaBella (2007: 37), excessive traction stress in an individual who is skeletally immature will therefore more likely result in an apophyseal avulsion fracture as opposed to a tendon injury or muscle strain. According to Grady and Goodman (2010: 37), the mechanism of injury of an avulsion fracture is a intense eccentric muscle contraction that may take place while sprinting – which is associated with the ischial tuberosity, or while kicking a ball – which is associated with the anterior superior iliac spine and anterior inferior iliac spine. As indicated by Moeller (2003 cited in LaBella 2007: 37), apophyseal avulsion fractures most commonly occur in adolescents between the ages of fourteen and eighteen years, with 80% being sports related. Moeller (2003 cited in LaBella 2007: 37) further mentions that the incidence rate of injury is higher in males as opposed to females.

2.1.5.5.3 Slipped Capital Femoral Epiphysis

A slipped capital femoral epiphysis (SCFE) is the most frequent complaint of the hip in adolescents (Grady and Goodman 2010: 177). SCFE happens at some stage in the adolescent growth spurt when biomechanical forces result in the proximal femoral physis to be posteriorly displaced therefore causing a shortening of the femoral neck (Grady and Goodman 2010: 177). The individual will experience lateral hip or groin pain and occasionally medial knee pain (Grady and Goodman 2010: 177).

2.1.5.6 Back Injury

Back injuries in the adolescent will include a discussion on spondylolysis and disc prolapse.

2.1.5.6.1 Spondylolysis

According to Anderson (2005) sports such as soccer which involve an extension or posterior arching of the back can lead to spondylolysis (or a fracture of the pars interarticularis (Zukotynski, Curtis and Grant *et al.* 2011: 5)). Repetitive movements such as bending places a large amount of stress on the pars interarticularis of the vertebrae (Zukotynski *et al.* 2011: 5). This may lead to the development of multiple micro-fractures resulting in a bone defect and can also lead to displacement of the vertebral body (Zukotynski *et al.* 2011: 5). Standaert and Herring (2007: 537) pars fractures commonly occur in soccer.

2.1.5.6.2 Disc Prolapse

According to Roach and Maffulli (2003: 63), adolescent sportsmen/sportswomen more commonly suffer from a prolapsed intervertebral disc as opposed to non-sporting adolescents. Afshani and Kuhn (1991: 271) highlight that disc prolapse in the adolescent occurs abruptly after exertion and is caused by trauma not degeneration. Disc prolapse most commonly occurs at the L4/L5 level of the spine and is due to an increased mechanical stress to this area (Boon *et al.* 2006: 1085). Disc prolapse is associated with a reduction in the visco-elasticity of the nucleus pulposis (soft central area (Seeley, Stephens and Tate 1998: 1042)) of the disc – leading to damage and essentially herniation (Boon *et al.* 2006: 1085). In adolescents the annulus fibrosis (fibrous material around the outer part of the intervertebral disc (Seeley, Stephens and Tate 1998: 1021)) consists of hyaline cartilage, which if torn can lead to a large disc herniation (Afshani and Kuhn 1991: 272). Individuals with a disc prolapse may present with radicular pain, sensory deficit, motor or muscle weakness, loss of bisymmetrical reflexes and sciatica (Boon *et al.* 2006: 1085).

2.1.5.7 Elbow Injury

The elbow often develops stiffness following trauma, and injury to the growth plate of the elbow can result in malformation such as the gunstock varus deformity which can occur after a supracondylar fracture (Roach and Maffulli 2003: 60). According to Roach and Maffulli (2003: 60), an elbow dislocation is common in sports such as gymnastics and soccer. In soccer, dislocations of the elbow can occur due to contact (Kocher, Waters and Micheli 2000: 127) such as collisions with other players. Dislocations of the elbow can be linked with fractures of the medial epicondyle of the humerus and of the neck of the radius (Roach and Maffulli 2003: 60). Roach and Maffulli (2003: 60) also stated that dislocations of the elbow can also be associated with damage to the median nerve or ulnar nerve. Traction apophysitis can occur at the insertion of the triceps into the epiphysis of the olecranon – however it rarely occurs in soccer and is more common in sports such as gymnastics, diving, wrestling and hockey (Roach and Maffulli 2003: 60).

2.1.5.8 Shoulder Injury

Seeley, Stephens and Tate (1998: 208) indicate that the shoulder girdle consists of the scapula or shoulder blade and the clavicle or collar bone. The clavicle is susceptible to injury in sports involving direct contact (Kocher, Waters and Micheli 2000: 120) such as soccer. According to Roach and Maffulli (2003: 60), clavicular injuries frequently occur in all sports. Other injuries to the shoulder include rotator cuff injuries, biceps tendon injuries, and dislocation - which are uncommon before the closure of the growth plate (Roach and Maffulli 2003: 60).

2.1.6 Injury Risk in Team versus Individual Sport

Theisen *et al.* (2013: 203) speculated that sportsmen/women involved in team sports bare a higher risk of injury than those who are involved in individual sports. Soccer is a team sport and players can get injured in a number of ways including non-contact mechanisms such as running (Howe 1996: 20) and contact mechanisms such as collisions and tackles (Oztekin *et al.* 2009: 23). A greater awareness of sport-participation risk factors and the monitoring thereof could aid in the prevention of sports injuries (Theisen *et al.* 2013: 203).

2.1.7 Risk Factors for Injury in the Adolescent

According to Grimmer, Jones and Williams (2000: 266), every year eight percent of adolescents who participate in sporting activities will drop out due to injury. Emery (2005: 180) pointed out that adolescents will have a greater opportunity of getting injured due to more time spent participating in sports.

As adolescents experience rapid skeletal development, they are at a greater risk of injury (Armstrong and van Mechelen 2000 cited in Emery 2005: 184). Reasons why adolescents over 13 years of age are at a higher risk of injury than younger children are because of the different levels of competition, different amounts of physical contact while playing sport, and size of the competitors (Emery 2005: 183). Taller and heavier individuals may be more vulnerable to injury due to larger forces being transferred and absorbed through soft tissue and joints (Emery 2005: 184). Other factors to consider include the link between poor diet and injury (Roach and Maffulli 2003: 59) which will be deliberated at a later stage in this literature review (2.2.3.3.7) as a part of the section on the female athlete triad.

Emery (2005: 182) has summarised risk factors for injury in adolescent sport into two basic categories. The two categories include risk factors of intrinsic nature and risk factors of extrinsic nature (Emery 2005: 182). These factors are either non-modifiable or potentially modifiable (Emery 2005: 182). According to Emery (2005: 182), potentially modifiable extrinsic risk factors include sports rules; playing time; playing surface; and equipment. Potentially modifiable intrinsic risk factors include fitness level; training; flexibility; strength; joint stability; biomechanics; balance; proprioception; psychological and social factors (Emery 2005: 182).

2.2 Female Soccer

2.2.1 Injury Incidence and Prevalence

In a study performed by Frisch, Croisier and Urhausen *et al.* (2009: 105), it was established that the incidence of injury in females is high in team sports. Females make up twenty-two percent of the world soccer playing population (Mandelbaum and Putukian 1999: 255). According to the South African Department of Sports and Recreation (2005: 10), 38.9% of female learners are motivated to play sport at high school if it forms part of the curriculum. Despite the fact that there is a rapid increase in the participation of females in sport, especially in soccer, little is known and understood about injury incidence for females in soccer (Jacobson and Tegner 2007: 85). Furthermore, there is paucity in the literature pertaining to the prevention of injury and risk factors for injury in female soccer (Lilley, Gass and Locke 2002: 2).

According to Mtshali *et al*. (2009: 165), injury prevalence in adolescent soccer is similar in males and females. In female high school soccer however, injury rates are less than adult professional soccer players, and this is most likely due to the amount of exposure that adolescent female soccer players received (Mtshali *et al*. 2009: 165). As indicated by Mtshali *et al*. (2009: 165), professional players have a much higher number of matches and training sessions than adolescent high school players. In the study performed by Mtshali *et al*., (2009: 163), it was found that the injury rate of female high school soccer players had a point prevalence of

33% and a 1-year prevalence of 46%. Furthermore, it was found that the ankle and knee were the most commonly injured parts of the body (Mtshali *et al*., 2009: 164). In Lilley, Gass and Locke's (2002: 4) study on female soccer players it was discovered that strains (35%) followed by sprains (31%) were the most common types of injury. In order to understand soccer in the female population, one has to consider both the benefits and risks associated with playing soccer.

2.2.2 Benefits of Playing Soccer

Putukian (1998 cited in Mandelbaum and Putukian 1999: 255) pointed out that female adolescents derive a great deal of significant benefits from playing soccer. These benefits will be discussed as follows.

2.2.2.1 Social and Psychological Factors

Social and psychological factors consist of an improved body image and hence self esteem and less depression (Putukian 1998 cited in Mandelbaum and Putukian 1999: 255). Furthermore, through the participation in sport there is the development of a better understanding of and participation in teamwork; a higher level of cooperation; motivation to set goals and the acceptance of others (Putukian 1998 cited in Mandelbaum and Putukian 1999: 255). Therefore, because of sporting activities which may promote social issues of acceptance, there is a higher graduation rate and less social problems such as teenage pregnancy, alcohol abuse and drug addiction (Putukian 1998 cited in Mandelbaum and Putukian 1999: 255).

2.2.2.2 Physical Factors

Physical factors include an increase and maintenance of a good bone mineral density (Hind and Burrows 2007: 26) and lean muscle mass (Eliakim, Barstow and Brasel *et al*. 1996: 540) which would ultimately lead to greater strength and fitness. According to Frost (1997: 1542), bones become stronger and more dense when large voluntary loads are placed on them. Furthermore, muscle contractions also put stress on bones which result in increased bone strength and density (Frost 1997: 1542).

As stated by Morris, Naughton and Gibbs *et al.* (1997: 1454), research regarding the benefits of exercise for lean muscle mass and increased bone mineral density or skeletal mineralization have focused more on the mature skeleton. However, Morris *et al.* (1997: 1454) argued that it is through the study of the adolescent population that a greater understanding has been achieved regarding the contribution of a number of factors to increased bone mineral density.

2.2.3 Risk Factors for Injury in the Female

Despite the benefits for females associated with participating in sport, there are a number of risks (Mandelbaum and Putukian 1999: 255). According to Backous, Friedl and Smith *et al.* (1988 cited in Emery 2005: 182), females are more vulnerable to injury as opposed to males in sports such as soccer. Steffen *et al.* (2008: 8) found in their study that seventy percent of female adolescents were injured previously in their soccer careers and the injury involved the lower extremity predominantly. Furthermore, the notion that there is a higher risk of injury in females is possibly due to a lower skill level (Emery 2005: 183); less training (Mandelbaum and Putukian 1999: 256); a possible lack of physical fitness as compared to their male counterparts (Mandelbaum and Putukian 1999: 256); less strength as opposed to their male counterparts (Mandelbaum and Putukian 1999: 256); inadequate rehabilitation following injury (Chomiak, Junge and Peterson *et al.* 2000 cited in Jacobson and Tegner 2006: 1); or is more physiologically related (Emery 2005: 183), such as the effects of certain hormones as discussed in 2.2.3.3.5.

2.2.3.1 Training and Fitness

According to Arendt and Dick (1995 cited in Mandelbaum and Putukian 1999: 256), female soccer players are injured at a higher rate than males. As asserted by Mandelbaum and Putukian (1999: 256), the reason for this difference includes less training and a lack of physical fitness (including aerobic and anaerobic fitness) in female athletes as opposed to male athletes. These differences are due to the training background of the individual, the intensity during training and the quantity of training (Mandelbaum and Putukian 1999: 256). As proposed by Mandelbaum and Putukian (1999: 256), the training period for elite female soccer players was about fifty percent of that of their male counterparts.

2.2.3.2 Strength

In the female athlete, there is less overall strength in the quadriceps and hamstrings as opposed to the male athlete (Huston and Wojtys 1996: 430) and according to Hewett, Stroupe and Nance *et al.* (1996: 772), females have greater strength imbalances in the lower extremities such as between the quadriceps and hamstring muscles. Strength imbalance between the quadriceps and hamstrings increase the risk of damage to the ligaments especially during cutting movements as the stronger quadriceps will exert greater forces on the ACL and the hamstrings will be unable to work against these forces due to inferior strength (Alentorn-Geli, Myer and Silvers *et al.* 2009: 714). It is further stated that generally female athletes are significantly weaker than males (Huston and Wojtys 1996: 427) – thus, the normal strength and support function of a muscle will be less evident in females which provides reasons for a higher incidence of injury.

2.2.3.3 Physiology

Females are physiologically very different to males and some of these differences make females more vulnerable to injury. Physiological factors to consider include the Q-angle of the lower limb (Lewis 2000: 465); pelvic width (Lewis 2000: 466); the femoral intercondylar notch (Lewis 2000: 467); joint laxity (Lewis 2000: 468); hormonal influence (Lewis 2000: 468); body composition (Lasalandra 2011); the female athlete triad which is the relationship between low energy, menstruation and reduced bone mineral density in females (Lasalandra 2011) and neuromuscular performance (Lewis 2000: 468) which involves the assessment of the coordination between nerves and the muscles.

2.2.3.3.1 Q-Angle

According to Pantano, White and Gilchrest *et al.* (2005: 967), the Q-angle of the lower limb is a measurement of the angle of the lines drawn from the anterior superior iliac spine and the patella, and the patella and the tibial tuberosity, and this line is no more than fifteen to twenty degrees in females normally. Horton and Hall (1989: 897) highlighted that the greater the Q-angle, the more the quadricep muscles pull on the patella which can lead to injury. In an investigation performed by Park and Stefanyshyn (2011: 394) it was found that the females had a greater Q-angle compared to males. Alentorn-Geli *et al.* (2009: 710) suggest that an increased Q-angle can increase the risk of ACL injury to the knee. This provides viability as the knee is the most common part of the body injured in female soccer players (Mtshali *et al*. 2009: 164). However, Soderman, Alfredson, Pietila *et al.* (2001 cited in Alentorn-Geli *et al.* 2009: 711) studied the effect of the Q-angle on injury in Swedish female soccer players and it was found that there was no significance in this relationship.

2.2.3.3.2 Pelvic Width

Essentially, it is the structurally wider pelvis and shorter femurs of the female that lead to a valgus orientation of the knee (Horton and Hall 1989: 898) – leading to an increased Q-angle. According to Horton and Hall (1989: 897), this increased Q-angle will cause the quadriceps to pull laterally on the patella hence cause conditions such as patella dislocation and chondromalacia patellae and will also exert stress on the knee soft tissue. According to Tumia and Maffulli (2002 cited in Park and Stefanyshyn 2011: 392), this will result in pressure on the patella lateral facet causing anterior pain of the knee which can lead to conditions such as patellofemoral syndrome.

2.2.3.3.3 Femoral Intercondylar Notch

According to Shelbourne, Davis and Klootwyk (1998: 404), clinical investigations of individuals' knees show that females have a narrower intercondylar notch than males. Tillman, Smith and Bauer *et al.* (2002: 42) assert that a narrower intercondylar notch is a causative factor of ACL injury. According to Shelbourne, Davis and Klootwyk (1998: 406), the ligaments of the ACL travel through the notch, therefore the narrower the notch the greater the chance of damage to the ligaments. However, despite the aforementioned association between intercondylar notch width in females and injury, Shelbourne, Davis and Klootwyk (1998: 407) support the notion that ACL tear rate and intercondylar notch widths are not considerably different between the genders. In soccer, Mandelbaum and Putukian (1999: 259) found that injuries to the ACL in females were very common which could lend support to the theory that a narrower intercondylar notch can in turn lead eventually to injury of the ACL.

2.2.3.3.4 Joint Laxity

Quatman, Ford and Myer *et al.* (2008: 2) states that an increased joint laxity or hypermobility increases normal joint range of motion. Active and passive physiological restraints assist in providing stability to joints and thus prevent joint injury (Quatman *et al*. 2008: 2). Ligaments are passive joint restraints and muscles are passive and active joint restraints (Quatman *et al.* 2008: 2). Hence, as asserted by Quatman *et al.* (2008: 2), changes in any of these structures during adolescent development may compromise joint stability and may lead to joint injury and loss of function. In a study performed by Quatman *et al.* (2008: 2), findings suggested that following the onset of puberty, females develop a greater generalized joint laxity as opposed to males. This greater joint laxity is likely to be associated with decreased passive joint stability in female athletes (Quatman *et al.* 2008: 4). According to Quatman *et al.* (2008: 4), the increase in joint laxity in females is most likely related to hormonal and anatomical changes that occur during puberty. Joint laxity provides greater potential for injury in sports involving awkward single-leg landing, stopping or sudden changes in direction (Ramesh, Von Arx and Azzopardi *et al.* 2005: 802) such as soccer.

2.2.3.3.5 Hormonal Influences

According to Lewis (2000: 468), females are constantly affected by a cyclic alteration in endogenous and exogenous hormone levels. Oestrogen and progesterone inhibit fibroblastic proliferation, therefore slowing down repair of damaged tissue following injury (Liu, Yu and Panossian *et al.* 1997 cited in Mandelbaum and Putukian 1999: 257). Furthermore, Liu, Al-Shaikh and Panossian *et al.* (1997 cited in Lewis 2000: 469) point out that collagen synthesis was found to be considerably reduced with an increase in estradiol (oestrogen) concentration. This resulted in structural changes and caused reduced ligamentous strength (Liu *et al*. 1997 cited in Lewis 2000: 469). In addition, Mandelbaum and Putukian (1999: 257) also proposed that oestrogen and relaxin cause an increase in joint laxity providing potential for injury. According to Lewis (2000: 469), there is a higher likelihood of injury during the ovulatory phase of the menstrual cycle when oestrogen levels are high. This could implicate that poor neuromuscular coordination could be just as important as reduced ligamentous strength due to increased oestrogen (Lewis 2000: 469). However, in a study by Daniuseviciute, Linonis and Barsiene (2012: 31) it was revealed that knee proprioception function is improved when there is an increase in oestrogen levels. Proprioception is associated with the control of balance (discussed in section on balance 2.3.1.3).

In certain conditions where there is a reduction or complete cessation of oestrogen production, new bone formation may be delayed, which means the individual may develop a low bone mineral density, and thus the individual can suffer from stress fractures in high-impact sports or in sports that involve repetitive stressors of mechanical nature such as running (Bennell, Matheson and Meeuwisse *et al.* 1999: 108).

2.2.3.3.6 Body Composition

Body composition will be discussed with emphasis on body mass index (BMI). According to the World Health Organisation (WHO) (2006), BMI is an index used to establish whether an individual is underweight, overweight or obese. It is calculated by mass in kilograms divided by height squared in metres (WHO 2006). In a study performed by Gittelsohn, Harris and Thorne-Lyman *et al.* (1996: 2996), it was found that the mean BMI of females was significantly higher than that of males. In a study done by Habib (2013: 96) on BMI parameters in adults between the ages of eighteen and seventy-two it was found that females had a higher mean BMI and body fat percentage then males. However, Vignerova, Humenikova and Brabec *et al.* (2007: 420) found an increase in the rate of low BMI amongst female adolescents in the Czech Republic. Caradas, Lambert and Charlton (2001: 115) evaluated BMI in South African adolescent females and found that black females had a higher BMI than females of other race groups. It was further identified by Caradas, Lambert and Charlton (2001: 119) that abnormal eating behaviours existed within this population. BMI is classified in the table below. Gittelsohn, Harris and Thorne-Lyman *et al.* (1996: 2993) did not categorize each specific age group in terms of the normal/overweight etc. BMI scores for all participants (age range of ten to sixty+ years) were grouped together in their study. This study follows this as all participants were grouped together and categorized according to a general BMI Classification.

Table 2.2 Body Mass Index Categorization

Classification	**BMI (kg/m2)**	**Sub-classification**		**BMI (kg/m2)**
underweight	< 18.50	Severe thinness		< 16.00
		Moderate thinness		16.00 - 16.99
		Mild thinness		17.00 - 18.49
normal range	18.5 - 24.99	normal		18.5 - 24.99
overweight	≥ 25.00	pre-obese		25.00 - 29.99
		Obese	obese class I	30.00 - 34.99
		(≥ 30.00)	obese class II	35.00 - 39.99
			obese class II	≥ 40.00

Source: World Health Organisation (apps.who.int/bmi/index.jsp?introPage=intro_3.html, accessed on the 5 August 2013).

McGraw, McClenaghan and Williams *et al.* (2000: 484) point out that a high fat percentage can prevent optimal functioning of the postural control system and can lead to a loss of balance. The relationship between BMI and balance will be discussed later in this literature review (2.3.4).

2.2.3.3.7 Female Athlete Triad

Lasalandra (2011) proposed that one of the most important factors that make females more likely to be injured than males in sports is a result of the “female athlete triad”. The three elements here include reduced energy due to abnormal eating (bulimia, anorexia); menstrual disturbances; and decreased bone mineral density (Lasalandra 2011).

According to Loucks, Verdun and Heath *et al.* (1998: 45), low energy availability can occur due to an inadequate caloric intake – which is insufficient dietary compensation for the quantity of energy used up as a result of exercise, or intentionally restricted or abnormal eating behaviour – such as bulimia or anorexia.

Low energy availability inhibits the release of hormones in the hypothalamus, pituitary glands and the ovaries (Loucks *et al.* 1998: 37). Thus, through inhibition of the hypothalamus there will be a suppression of lutenizing hormone (LH) production which stimulates oestrogen secretion (Guyton and Hall 1997: 599).

According to Warren and Pelroth (2001: 4), low levels of LH in the blood limits oestrogen production from the ovaries which causes hypooestrogenemia and oligomenorrhea (irregular menstrual cycles) or amenorrhea (cessation of menstruation).

It is further mentioned by Martin, Golden and Carlson *et al.* (2008: 211) that reduced glucose availability to the brain may also be accountable for a decrease in LH pulsatility which will in turn have an effect on normal oestrogen production.

During adolescence, amenorrhea (cessation of menstruation) and insufficient caloric intake can negatively affect the accumulation of peak bone mineral density – leading to osteoporosis (Pantano 2009: 3) and as a result a greater potential for injury.

2.2.3.3.8 Neuromuscular Performance

According to Quatman *et al.* (2008: 5), female athletes, when compared to male athletes demonstrate neuromuscular shortfalls that may be related to their physical development. During puberty males exhibit a neuromuscular spurt (Quatman *et al.* 2008: 5). In order to fully comprehend the neuromuscular difference between males and females, ACL injuries will be discussed as it is one of the most common injuries in female soccer (Bowerman, Smith and Carlson *et al.* 2006: 145).

Hewett, Lindenfeld and Riccobene *et al.* (1999: 703) proposed that the explanation for the higher incidence of an ACL injury in females is due to their inadequate neuromuscular skills. As pointed out by Beard, Kyberd and Fergusson *et al.* (1993: 312), there is a reflex arc between the ACL and the hamstring muscles which mediates a protective reflex contraction of the hamstrings when the ACL is strained. A reflex arc is a unit of the nervous system that consists of a sensory receptor, a sensory neuron, association neurons, a motor neuron and an effector organ (such as a skeletal muscle) (Seeley, Stephens and Tate 1998: 370). Huston and Wojtys (1996: 433) found in their study on female electromyography (EMG) neuromuscular patterns that females relied on their quadriceps muscles in reaction to anterior tibial translation. The quadriceps is the major antagonist of the ACL while the hamstring is an agonist and both provide protection for the ACL (Mandelbaum and Putukian 1999: 256). Mandelbaum and Putukian (1999: 256) pointed out that female athletes have a higher average quadriceps activity and recruit the quadriceps before the hamstrings. According to Hewett, Paterno and Noyes (2000: 81), greater quadricep activity is a risk factor for anterior tibial bone subluxation and hence ACL strain. When the knee is flexed greater than forty-five degrees, contraction of the quadriceps will increase risk of sprain to the ACL and resultant injury (Hewett, Paterno and Noyes 2000: 81). This can occur during intense knee extension when sprinting towards the soccer ball or when extending the knee during an attempt at a powerful kick (Howe 1996: 22).

During sport, the sportsman/sportswoman relies on neuromuscular coordination (e.g. hamstring-reflex arc), proprioception, reflexes and reaction time for optimal performance (Mandelbaum and Putukian 1999: 257). A loss or imbalance of any of these elements will lead to injury. Essentially, protective muscle reaction times can be diminished with proprioception, coordination and agility training programmes which will decrease injury rates (Lewis 2000: 470). According to Stillman (2002: 668), the proprioceptive system provides the brain with information vital for the process of balance. Furthermore, as highlighted by Emery (2005: 182), poor balance does increase injury risk in sport.

2.3 Balance

According to Ragnarsdottir (1996: 370), balance is a complex motor skill and can also be referred to as a means of controlling posture or ‘postural control’. Balance or postural control can therefore be defined as the ability of the body to remain stable over its base of support (Horak 1987: 1881) with minimum sway or maximum steadiness. Fitzpatrick, Rogers and McCloskey (1994: 396) state that when standing, sway refers to the movement of the COG in a forward, backward or lateral direction. Dickstein and Abulaffio (2000: 367) emphasize that an increase in sway represents a disturbance of postural control. The base of support of an individual refers to the area of all contact points with the ground such as the feet during quiet standing (Horak 2006: 8). Furthermore, the base of support can be increased by spacing the feet further apart (Horak 2006: 9). So, if an individual is standing with one foot on the ground the base of support is the area of that one foot, and if a person is standing with both feet on the ground as well as a walking stick the base of support is the area of both feet and the part of the walking stick that is touching the ground.

The process of balance relies in part on information from the sensory system which includes the vestibular, visual, and somatosensory sub-systems. This information is then integrated, so that the body adjusts to its position in space (Horak 2006: 9). According to Nolan (2009: 1), balance not only involves the sensory system, but also involves the skeletal muscle system and the central nervous system (CNS). In order to understand this, the process of balance refers to the ability of the CNS to integrate information received from the somatosensory, vestibular, and visual systems (Riemann and Guskiewicz 2000: 49). The input from these systems allows the individual to sense their body position in relation to gravity and their surroundings (Riemann and Guskiewicz 2000: 37). The CNS will interpret the information and coordinated nervous signals are sent to the appropriate muscles so corrective actions to maintain balance is carried out (Lephart, Pincivero and Rozzi 1998: 151, Kejonen 2002: 15). The centre of gravity (COG) of the individual will thus be preserved. Lephart, Pincivero and Rozzi (1998: 150) proposed that the visual and somatosensory systems are the main contributors to balance. Furthermore, as pointed out by Balter, Stokroos and Akkermans *et al.* (2004: 74), in sports (such as soccer) which require fast balance control responses, the visual and somatosensory systems are the predominant contributors. It is also understood that the more highly trained the athlete – such as elite athletes, the greater the contribution of the vestibular system to balance control (Balter *et al.* 2004: 74). Each of the three systems mentioned will be discussed.

2.3.1 Sensory Systems and Balance

2.3.1.1 Vestibular System

The sensory system includes the vestibular, visual and somatosensory systems. According to Agrawal, Carey and Santina *et al.* (2009: 938), the vestibular system is an important component in relation to balance control.

The vestibular system is situated in the inner ear and it consists of the semicircular canals, otoliths and maculaes (Guyton and Hall 1997: 450). The inner ear is a maze of bony chambers called the bony labyrinth which is situated in the temporal bone of the skull (Marieb 2000: 253). Marieb (2000: 253) points out that the three divisions of the bony labyrinth include the cochlea, the vestibule and the semi-circular canals. The bony labyrinth is filled with a plasma-like fluid which is known as perilymph, and suspended in the perilymph is a membranous labyrinth (Marieb 2000: 253). The membranous labyrinth consists of a fluid known as endolymph (Marieb 2000: 253). According to Seeley, Stephens and Tate (1998: 487) the cochlea is the major sensory area for hearing while the semicircular canals and vestibule are integral parts of the equilibrium or balance system. Morningstar, Pettibon, Schlappi *et al.* (2005: 4) propose that the vestibular system is fundamental in promoting upright posture which is important during soccer.

The vestibule can be further divided into the utricle and saccule (Seeley, Stephens and Tate (1998: 494). As indicated by Marieb (2000: 254), in the membranous sacs of the vestibule are receptors known as maculae. Within the maculae of the utricles and saccules are hair cells which project cilia into a gelatinous layer (Seeley, Stephens and Tate 1998: 494) which is called the otolithic membrane (Marieb 2000: 255). The otolithic membrane consists of small calcium salt stones known as otoliths (Marieb 2000: 255). As the head moves, the otoliths move which in turn creates a pull on the otolithic membrane – which stimulates the hairs (Marieb 2000: 255). According to Guyton and Hall (1997: 451) the hairs point in different directions so certain hairs are stimulated when the head bends anteriorly or posteriorly or to the side. Once the hair cells are stimulated, impulses will be sent to the central nervous system (CNS) (which includes the brain) via the vestibulocochlear nerve (Seeley, Stephens and Tate 1998: 497). The brain will receive information pertaining to the position and acceleration of the head in space (Seeley, Stephens and Tate 1998: 495). Following this, the brain will stimulate certain muscles in the neck and back to contract in order for the head to return to a normal balanced position (Seeley, Stephens and Tate 1998: 495). The utricle and saccule identify linear accelerations of the head with the utricle more specifically identifying changes in head position relative to gravity, and the saccule helping with regard to the maintenance of head position in relation to the visual field (Morningstar *et al.* 2005: 4). Essentially, as asserted by Marieb (2000: 254), the maculae are important in static equilibrium.

According to Seeley, Stephens and Tate (1998: 495) there are three semicircular canals which are placed at ninety degrees to each other. The three canals will allow an individual to identify movement in a number of directions (Seeley, Stephens and Tate 1998: 495) – thus, regardless of which direction one moves in, there will be receptors to detect the movement (Marieb 2000: 255). As pointed out by Marieb (2000: 255), within each semicircular canal there is a receptor region called the cristae ampullaris which consists of a group of hair cells that is covered by a gelatinous cap known as the cupula. According to Marieb (2000: 256), when the head rotates, the endolymph in the canal remains stationary and then starts to move in the opposite direction to the rotation of the head which pushes the cupula in a direction opposite to the body’s motion. The hair cells will then be stimulated and impulses will be transmitted via the vestibular nerve to the cerebellum (Marieb 2000: 256). When this angular motion stops suddenly, the endolymph will flow in the same direction as the original rotation of the head and the cupula’s movement will be reversed – which will in turn cause the hair cells to reduce their rate of sending of impulses to the vestibular nerve (Marieb 2000: 256). As mentioned by Guyton and Hall (1997: 452), the individual will now sense a cessation of rotation. Essentially, the semicircular canals are important in dynamic balance (Marieb 2000: 256). Kinzey and Armstrong (1998 cited in Cachupe *et al.* 2001: 98) point out that dynamic balance is associated with the body’s preservation of balance when conditions cause the COG of the individual to move due to muscular activity.

As highlighted by Guyton and Hall (1997:452) through the mechanism of action of the semicircular canals, a loss of equilibrium will be predicted ahead of time. During soccer, a player can be running at a rapid speed in the forward direction when he/she suddenly moves sideways (cutting movement). It is the function of the semicircular canals to predict this change of movement the moment it starts happening and thus provide the CNS with this information so that the appropriate corrective measures take place - such as the contraction of certain muscles involved in postural control (Guyton and Hall 1997: 452). Thus, the equilibrium control centres will be given sufficient time to make the appropriate adjustments in order to avoid potential balance control problems such as a fall (Guyton and Hall 1997: 452). According to Seeley, Stephens and Tate (1998: 498) the body will respond to these nervous stimuli by stimulating the appropriate postural muscles to contract in order to promote balance.

To promote an understanding of the interaction between the vestibular system and the CNS, a diagram will be used. As is seen in figure 2.1 (marked 1 on figure), afferent axons from the vestibular ganglion pass through the vestibular nerve on the way to the vestibular nucleus which also receives input from other sources such as the proprioceptive system in, for example the legs and the visual system (Seeley, Stephens and Tate 1998: 498). According to Seeley, Stephens and Tate (1998: 498), vestibular neurons send projections to the cerebellum, which is involved in the control of postural muscles, and to the motor nuclei (this includes the oculomotor nuclei, the trochlear nuclei, and the abducens nuclei) all of which control the extrinsic muscles of the eye (this is marked 2 on the diagram). Furthermore, vestibular neurons also project to the posterior ventral nucleus of the thalamus (this is marked 3 on the diagram) (Seeley, Stephens and Tate 1998: 498). Lastly, thalamic neurons project to the vestibular area of the cortex (marked 4 on diagram) (Seeley, Stephens and Tate 1998: 498).

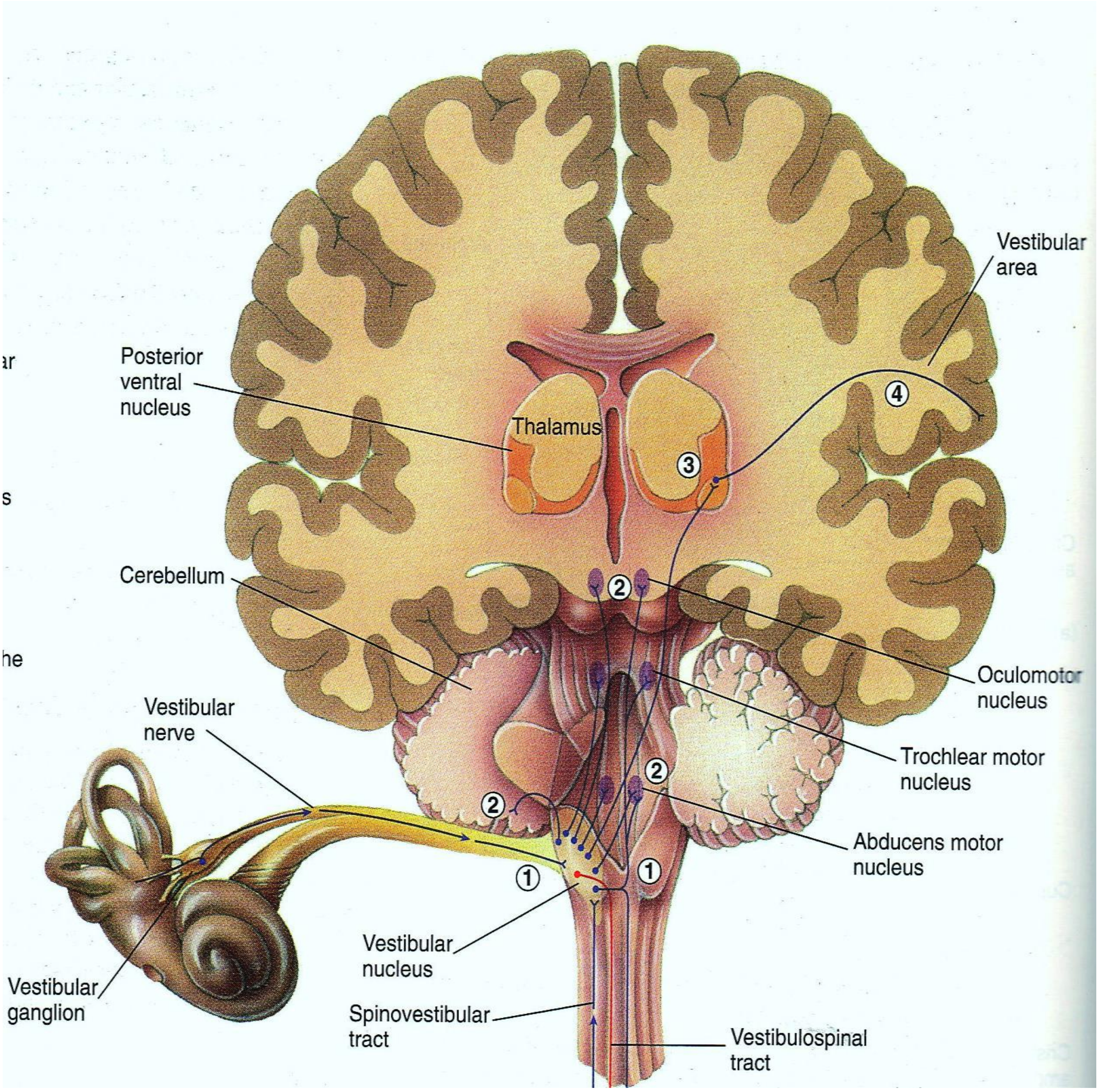

Figure 2.1 CNS and Vestibular System Relationship (Seeley, Stephens and Tate 1998: 498).

As has been illustrated, the vestibular system provides the CNS with information that evaluates the gravitational, linear and angular accelerations of the head in space (Riemann and Guskiewicz 2000: 38). However, according to Nashner (1993 cited in Riemann and Guskiewicz 2000: 38), the vestibular system does not provide information regarding orientation in relation to external objects and thus plays a minor role in balance maintenance when the visual and somatosensory systems are providing more accurate information to the brain.

2.3.1.2 Visual System

According to Guyton and Hall (1997: 452), the visual system plays a fundamental role in the maintenance of balance. When there is proprioceptive or vestibular loss, vision can help to maintain balance (Guyton and Hall 1997: 452). Small movements of the body will cause the images on the retina to start moving slightly, and this will stimulate the equilibrium control centres to correct balance (Guyton and Hall 1997: 452). Lephart, Pincivero and Rozzi (1998: 149) highlight that injury leads to a loss of normal somatosensory function as a result of disruption to the proprioceptors. Thus, if a soccer player is injured and as a result of this has proprioceptive disruption, the contribution of their visual system to balance will increase (Paillard 2012: 166).

As stated by Morningstar *et al.* (2005: 3), visual input aids in the maintenance of an upright posture by keeping the head in a fixed position. Furthermore, as indicated by Morningstar *et al.* (2005: 4), the extraocular muscles of the eye contain proprioceptors which will relay proprioceptive information to the brain.

Essentially, Buchanan and Horak (1999: 2325) assert that as a result of visual input keeping the head and trunk in a fixed position, the centre of mass (COM) of the body will be kept stable within the individuals' base of support.

2.3.1.3 Somatosensory System

The somatosensory system includes the tactile senses which detect the sensations of touch, pressure and vibration (Riemann and Guskiewicz 2000: 39); and the proprioceptors (Seeley, Stephens and Tate 1998: 458). The proprioceptors transmit information to the brain pertaining to the position and movement of joints (Fitzpatrick, Rogers and McCloskey 1994: 395) as well as balance (Stillman 2002: 667). Receptors involved in joint movement and position will convey information in relation to body and limb position to the CNS after which information will be sent via motor neural pathways in order for the appropriate muscles to be stimulated to contract so that postural control adjustments can be made through certain movement strategies including the ankle strategy, the hip strategy and the stepping strategy (Riemann and Guskiewicz 2000: 49) (discussed in 2.3.2.1, 2.3.2.2 and 2.3.2.3). Furthermore, this will permit reflex protection of the joints from injury and prevent the individual from falling (Stillman 2002: 675). This is vital in soccer as there are constant changes in direction, jogging, sprinting, jumping and collisions therefore postural control is fundamental in order to prevent falls. When there is damage to the proprioceptors as a result of injury the contribution of the somatosensory system to balance will thus be negatively affected (Kennedy, Alexander and Hayes 1982 cited in O'Connell, George and Stock 1998: 137).

2.3.1.3.1 Somatosensory Receptors

According to Lephart, Pincivero and Rozzi (1998: 150) each tactile and proprioceptive receptor in the proprioceptive or somatosensory system can be divided into two functional groups – slow adapting and fast adapting – this relates to the manner in which the receptor responds to stimuli. As pointed out by Riemann and Guskiewicz (2000: 39), the possession of both types of receptors is vital in order for the postural control system to operate during activities of static, dynamic and functional nature.

2.3.1.3.2 Tactile Sense Organs

Riemann and Guskiewicz (2000: 39) proposed that touch; pressure and vibration sensations are transmitted to the CNS via tactile sensory receptors. Hair follicle cells are the main mechanoreceptors in areas of hairy skin, Meissner corpuscles (which are fast adapting) and Merkel receptors (which are slow adapting) are found in hairless skin (Riemann and Guskiewicz 2000: 39). Ruffini corpuscles (which are slow adapting) and Pacinian corpuscles (which are fast adapting) are found in the subcutaneous tissue (Riemann and Guskiewicz 2000: 39).

According to Seeley, Stephens and Tate (1998: 460), slow adapting Ruffini corpuscles detect states of constant touch or pressure and they react to stretching or deformation of the skin and deeper tissue. Guyton and Hall (1997: 384) further point out that Ruffini corpuscles are also found in joints and provide information regarding the amount of rotation of the joint. Fast adapting Pacinian corpuscles are stimulated by deep pressure to the tissue, vibration and transmit proprioceptive information about joint position to the brain (Guyton and Hall 1997: 384). Free nerve endings are also found abundantly in the skin and become activated during high degrees of deformation of mechanical nature (Guyton and Hall 1997: 383). According to Paillard (2012: 166) exercise has a positive effect on the responsiveness of the sensory receptors involved in balance control.

2.3.1.3.3 Muscle Mechanoreceptors

Muscle mechanoreceptors include muscle spindles and golgi tendon organs (Riemann and Guskiewicz 2000: 39). According to Seeley, Stephens and Tate (1998: 459), muscle spindle fibres and golgi tendon organs provide the CNS with feedback as to the status of each muscle and tendon respectively.

Muscle spindles are made up of afferent nerve endings that are wrapped around a few muscle fibres that are adapted for this (these muscle fibres are also known as intrafusal fibres), and all these structures are enclosed in a connective tissue casing (Riemann and Guskiewicz 2000: 40). Riemann and Guskiewicz (2000: 40) further assert that the intrafusal fibres function as the sensory organs of the muscle spindle. According to Seeley, Stephens and Tate (1998: 459), muscle spindles react to the stretching of a muscle and as further highlighted by Riemann and Guskiewicz (2000: 39) will transfer information to the CNS regarding the rate and scale of the stretch. The information will be sent via afferent neurons to the CNS and as a result of this alpha neurons in the CNS will send nerve impulses back to the muscle and stop it from stretching by stimulating it to contract (Seeley, Stephens and Tate 1998: 400). In terms of postural control, when an individual leans to the side the muscles on the opposite side of the trunk will stretch (Seeley, Stephens and Tate 1998: 399). As a result, the muscle spindles will be stimulated and therefore the muscles will contract in order for normal postural balance to be restored (Seeley, Stephens and Tate 1998: 399). This is seen in soccer when a goalkeeper leans to the side in order to stop a ball.

As indicated by Riemann and Guskiewicz (2000: 39), golgi tendon organs are located in sequence in musculotendinous fibres found at the point where muscles and tendons meet and as pointed out by (Seeley, Stephens and Tate 1998: 459) they are also enclosed in a connective tissue casing. Seeley, Stephens and Tate (1998: 401) state that golgi tendons will sense tension in a tendon and this information will be transmitted via afferent neurons to the CNS and as a result of this alpha neurons in the CNS will send nerve impulses back to the associated muscle causing it to relax therefore reducing the tension placed on the tendon. Golgi tendons therefore have a protective function as they inhibit damage to muscles and tendons due to excessive tension (Seeley, Stephens and Tate 1998: 460). During soccer there are constant changes in direction and sudden movements (Seeley, Stephens and Tate 1998: 401). This will place a lot of strain on the tendons leading to injuries such as hamstring tendon strains (Seeley, Stephens and Tate 1998: 401).

2.3.1.3.4 Function of the Somatosensory System

The main function of the somatosensory system is to provide the postural control system with information about the orientation of segments of the body to each-other and to the support surface (Nashner 1993 cited in Riemann and Guskiewicz 2000: 40). Essentially, as proposed by Horak, Nashner and Diener (1990 cited in Riemann and Guskiewicz 2000: 40), somatosensory information derived from the feet is the dominant sensory input to balance under normal surface conditions. Furthermore, somatosensory input also compensates for vestibular deficit and eye closure in maintaining balance (Horak, Nashner and Diener 1990 cited in Riemann and Guskiewicz 2000: 40). As pointed out by Lephart, Pincivero and Rozzi (1998: 150) the somatosensory system and the visual system are main the mediators of balance and postural control.

Figure 2.2 illustrates the various neural pathways associated with the somatosensory system. “1” in the diagram represents the subconscious reflexes of the body that protect the joints from injury (Stillman 2002: 671). “2” in the diagram reflects the spinocerebellar pathway where proprioceptive information is sent to the cerebellum in order for actual movements detected by the proprioceptors to be analysed (Stillman 2002: 672). In “3”, the spinomedullary pathway transmits proprioceptive information to the brain from the lower limb, and the cuneate transmits proprioceptive information to the brain from the upper limb (Stillman 2002: 672). “4” represents corollary discharge which includes the interpretation of the received information and the response – be it inhibitory or stimulatory (Stillman 2002: 672).

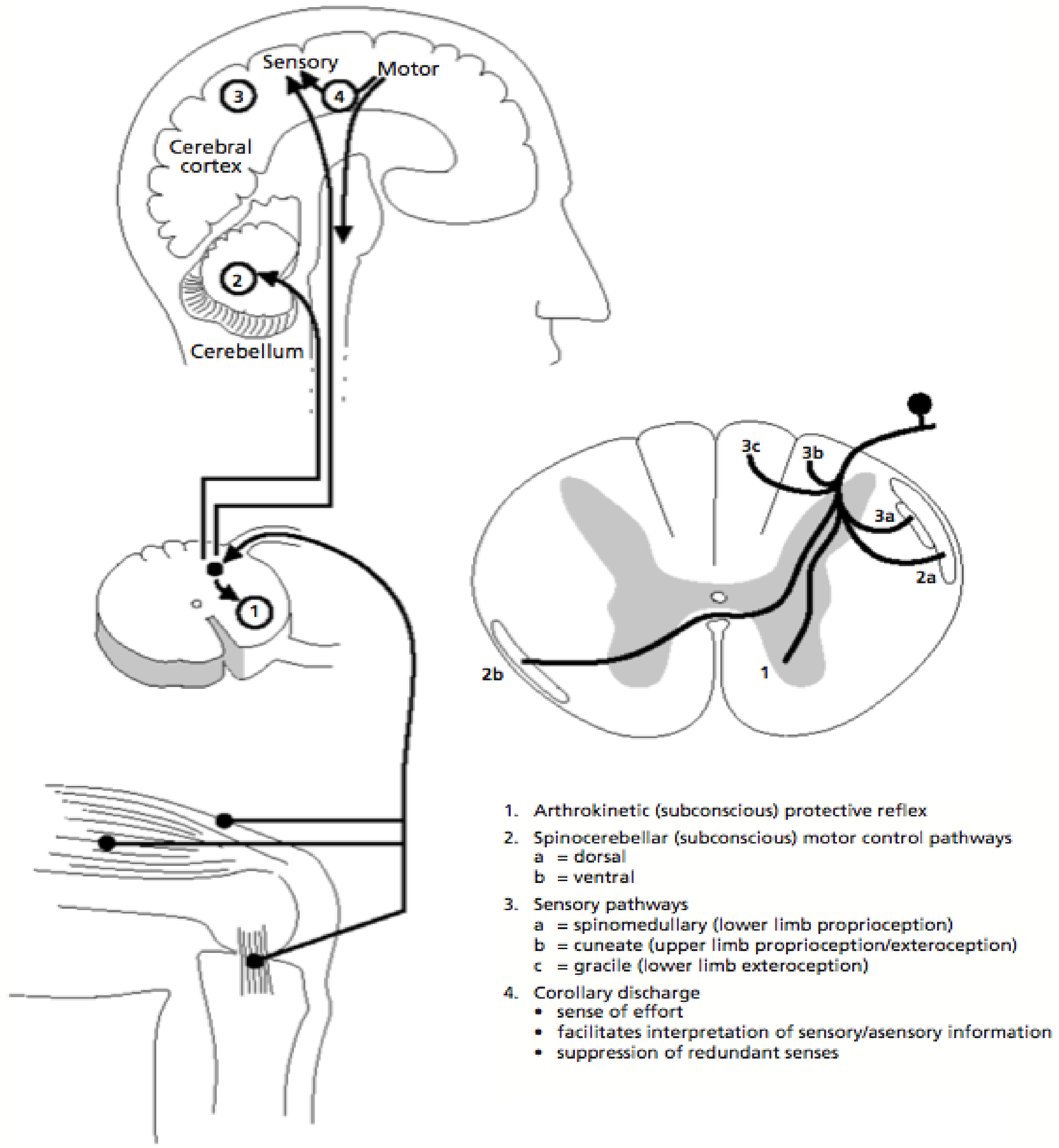

Figure 2.2 Proprioceptive System Pathways (Stillman 2002: 671).

This study involves an assessment of the relationship between injury and balance in a population with a normal functioning vestibular and visual system therefore; injury to the proprioceptors is an important component.

The four main causes of injury to the proprioceptors are:

1. An increase in age (Barrett, Cobb and Bentley 1991: 53).
2. Ligamentous injury (Beard *et al.* 1993: 312).
3. Peripheral neuropathy (Simoneau, Derr and Ulbrecht *et al.* 1996: 459).
4. Osteoarthritis (Barrett, Cobb and Bentley 1991: 53).

The second cause would most likely be associated with the population in this study as subjects were adolescents with no history of systemic disease.

2.3.1.3.5 The Somatosensory System and Postural Sway

Fitzpatrick, Rogers and McCloskey (1994: 396) state that when standing, postural sway refers to the movement of the COG in a forward, backward or lateral direction. Furthermore, when an individual is standing still their body continually displays low amplitude motion (Riley and Clark 2003: 45). According to Fitzpatrick, Rogers and McCloskey (1994: 396), information about postural sway originates from mechanoreceptors and tactile sense organs in the feet, joint receptors in the ankles and proprioceptors in the muscles of the legs. Once postural sway is determined by the CNS, the calf muscles of the lower leg are stimulated to contract if the postural sway is in an anterior or posterior direction, and the hip adductors, gluteus muscles of the buttocks and the peroneal muscles of the ankles are stimulated to contract if the postural sway is in a lateral direction (Fitzpatrick, Rogers and McCloskey 1994: 396).

Both the tactile sense organs and the muscle mechanoreceptors have a significant role in the control of posture and hence postural stability and sway. Fitzpatrick, Rogers and McClosky (1994: 396) proposed that as a result of the large size and weight of the body as opposed to the size of the feet, the cutaneous receptors of the feet are highly sensitive to slight changes in body posture thus are able to provide information about posture to the CNS continuously. According to Burke, Dickson and Skuse (1991: 445), the cutaneous receptors of the feet - which include the tactile sense organs, have been found to stimulate muscles of the lower extremity due to reflex muscle activation. Stillman (2002: 669) pointed out that cutaneous receptors provide the CNS with proprioceptive information especially during dynamic activity (Riemann and Guskiewicz 2000: 41, Stillman 2002: 670). Furthermore, Kavounoudias, Roll and Roll (2001 cited in Stillman 2002: 670) found that cutaneous receptors in the sole of the foot provide information regarding limb posture which assists the proprioceptors in determining limb position. In a study performed by Mazzaro, Grey and do Nascimento *et al.* (2006: 722) it was found that cutaneous receptors of the sole of the foot help to activate leg muscles such as the soleus during walking. This was speculated to be due to increased load in certain regions of the foot (Mazzaro *et al.* 2006: 722). As indicated by Guyton (1991 cited in Riemann and Guskiewicz 2000: 41), during static stance these cutaneous receptors provide the postural control system with information pertaining to whether weight is distributed equally between the two feet and whether weight is also distributed more anteriorly or posteriorly on each foot.

Lephart, Pincivero and Rozzi (1998: 150) indicated that mechanoreceptors such as muscle spindle fibres contribute to proprioception more than cutaneous receptors. It was also found that certain mechanoreceptors in the knee joint and adjacent ligaments transmit information to the CNS regarding joint acceleration and deceleration (Lephart, Pincivero and Rozzi 1998: 150). Lephart, Pincivero and Rozzi (1998: 153) further highlight that a reduction in sensory information from mechanoreceptors in the ankle can lead to chronic ankle instability and poor postural control and hence balance following injury.

Following the integration of information from the vestibular, proprioceptive and visual systems, the appropriate muscles will be stimulated to contract in order to produce the postural change required. The postural change achieved as a result of the aforementioned muscular responses will result in the body's COG being maintained over its base of support. Postural control plays a fundamental role in keeping the vertical projection of the COG within this base of support (Paillard

2012: 163). Postural sway is measured as an indicator of balance and the control of balance (Sturnieks, Arnold and Lord 2011: 1).

2.3.2 Postural Strategies and Balance

The ankles, knees and hips are located between the base of support of an individual and their COG which allows for the maintenance of posture when standing still, walking, running and changing directions (Riemann and Guskiewicz 2000: 41). According to Riemann and Guskiewicz (2000: 41), the body has a particular way in which the appropriate muscles are stimulated to contract when the body requires postural and hence balance correction. This includes the ankle strategy, the hip strategy and the stepping strategy (Riemann and Guskiewicz 2000: 37). Furthermore, the movements associated with the ankle, knee and hip joints are controlled by the contractions of the muscles of the legs that act in opposition such as the quadriceps – hamstrings and gastrocnemius/soleus (calf muscles) - anterior tibialis (shin muscle) (Riemann and Guskiewicz 2000: 41). This opposition muscle contraction is to prevent unnecessary rotation of the joints and assists in maintaining the COG of the individual over their base of support when their balance is disrupted (Riemann and Guskiewicz 2000: 41).

Essentially, as highlighted by Horak and Nashner (1986 cited in Riemann and Guskiewicz 2000: 42), the effectiveness of the ankle, hip and stepping strategies in maintaining the COG over the base of support is dependent on the size of the base of support, the COG in relation to the limit of stability (LOS), and the movement of the individual.

‘The Limits of stability (LOS) boundary refers to the maximum anterior-posterior (A-P) and medial-lateral (M-L) angles that keep the vertical projection of the COG within the base of support’ (Riemann and Guskiewicz 2000: 37). When the amount of postural sway exceeds the angle associated with the LOS and the COG vertical projection moves beyond the base of support, the individual will fall unless the ankle, hip or stepping strategies make the necessary postural adjustments (Nashner 1993 cited in Riemann and Guskiewicz 2000: 37). There is normally a change in the COG alignment in relation to the LOS when an individual has an injury such as an ankle or knee sprain (Riemann and Guskiewicz 2000: 42). Thus, an individual's limit of stability will provide a good indication of their dynamic balance control. Essentially, dynamic balance refers to the balance of an individual when dynamically challenged (Hrysomallis, McLaughlin and Goodman 2006: 289). Furthermore, according to Kinzey and Armstrong (1998 cited in Cachupe *et al.* 2001: 98), dynamic balance is associated with the body's preservation of balance when conditions cause the COG of the individual to move due to muscular activity. According to Winter (1995: 212) the hip abductors and adductors promote postural stability hence balance in a medial and lateral direction; the quadriceps, gluteus maximus and hamstrings promote balance in the posterior direction (Kuo and Zajac 1993: 145); and the hamstrings, tibialis anterior, gastrocnemius promote balance in the forward direction (Kuo and Zajac 1993: 145).

Riemann and Guskiewicz (2000: 42) indicate that the ankle strategy involves a distal to proximal activation of muscles (gastrocnemius – hamstrings – lumbar-paraspinals (lower back muscles) – trapezius (upper back muscles)), the hip strategy uses early proximal hip and trunk muscle activation (proximal to distal activation), and the stepping strategy uses an early activation of the hip abductors and ankle co-contraction. These three movement strategies involve the activation of certain muscles of the lower extremity in a specific order to bring the body back into balance (Riemann and Guskiewicz 2000: 42).

2.3.2.1 Ankle Strategy

According to Horak (1987: 1882) and Riemann and Guskiewicz (2000: 42), the ankle strategy allows for a shifting of the vertical projection of the COG back within the LOS by rotating the body over the ankle joints while the knee and hip joints remain still. The ankle strategy is commonly used when the individual is standing fairly upright with a static posture on a firm surface and it involves the contraction of either the gastrocnemius or the anterior tibialis muscles in order to maintain balance (Riemann and Guskiewicz 2000: 42). It is pointed out by Riemann and

Guskiewicz (2000: 42) that the ankle strategy is most effective in providing minor adjustments to the movement of the COG when the COG is within the LOS.

2.3.2.2 Hip Strategy

As stated by Horak (1987: 1882), the hip strategy refers to the movement of the COG through an extension or flexion of the hips and a rotation of the ankles. The hip strategy is used when the ankle strategy is unable to maintain balance when there are greater balance disturbances and when the COG is very close to the LOS boundary (see figure 2.4). An example of this could be when an individual stands on a narrow beam (Horak 1987: 1882). Furthermore, Winter (1995: 212) proposes that abductor and adductor muscles of the hips also help with balance from side to side (or medial to lateral). Individuals who have somatosensory loss are more reliant on the hip musculature to retain the COG position and hence balance (Riemann and Guskiewicz 2000: 42). Hubbard, Kramer and Denegar *et al.* (2007 cited in Wikstrom, Naik and Lodha *et al.* 2010: 411) highlighted that there is also an increase in the possibility of hip injury following ankle injury as a result of the greater reliance on the hip strategy.

2.3.2.3 Stepping Strategy

As asserted by Horak (1987: 1882), the stepping strategy is only used when the other strategies are unable to return the individual to a normal balanced state. This strategy will involve a sudden step, hop or stumble in order to move the COG back within the LOS boundary (Horak 1987: 1882).

2.3.2.4 Fatigue

According to Paillard (2012: 163), muscular exercise generates fatigue of the involved muscles, thus, the control of posture and the integration of sensory information and muscle stimulation leading to the movement strategy is negatively affected. As proposed by Vuillerme, Danion and Forestier *et al.* (2002: 134) muscle fatigue causes a loss of postural control due to the less than optimal functioning of the proprioceptors. Yaggie and McGregor (2002: 227) found in their study that fatigue to the ankle stabilizing muscles leads to poor stability and hence balance. Vuillerme *et al.* (2002: 134) pointed out that when the ankles become fatigued (which would happen during the running, turning and cutting manoevers associated with soccer), the CNS starts to rely more on other methods of input to balance control such as the vestibular system and the proprioceptors in the knees and hips. Therefore, as highlighted by Rozzi, Yuktanandana and Pincivero *et al.* (2000: 379) a change in joint proprioception results in the joint being unable to produce protective reactive muscle stimulation providing potential for injury. Armstrong, Ogilvie and Schwane (1983 cited in Yaggie and McGregor 2002: 227) add that following injury to the muscle reduced strength can occur leading to poor balance.

2.3.3 Injury and Balance

Guskiewicz and Perrin (1996b: 56) indicate that musculoskeletal injury to the lower limb can lead to poor somatosensory function. Stretched or damaged ligaments fail to provide proprioceptive information to the CNS necessary for the maintenance of balance (Riemann and Guskiewicz 2000: 45). According to Guskiewicz and Perrin (1996b: 56), research has revealed that ligament impairment in the ankle and knee leads to reduced joint proprioception and resultant poor balance. As highlighted by Riemann and Guskiewicz (2000: 45), a reduced reflex excitation or inhibition of the muscles adjacent to the damaged ligaments can occur which leads to poor protection of the joint. Essentially, these aforementioned elements discussed may result in a progressive degeneration of the joint and cause deficits in the movement function of the joint and balance (Riemann and Guskiewicz 2000: 45).

2.3.3.1 Ankle Injury and Balance

According to Freeman, Dean and Hanham (1965: 678) and Riemann and Guskiewicz (2000: 45), during injury to the lateral ligaments of the ankle, joint proprioceptor fibres are damaged as they possess poor tensile strength. When the ankle is sprained there is a deficit in reflex protective stabilisation of the ankle which results in poor stability of the ankle (Freeman, Dean and Hanham 1965: 678). Freeman, Dean and Hanham (1965: 678) highlight that this deficit in reflex stabilisation is due to damage to the proprioceptors which leads to poor transmission of information from the proprioceptors to the CNS, therefore the balance ability of the individual will be negatively affected.

Friden, Zatterstrom and Lindstrand *et al.* (1989 cited in Riemann and Guskiewicz 2000: 46) performed a study where they attempted to identify balance-related differences between injured and uninjured ankles. This study was performed with the use of a computerized strain gauge force plate (Riemann and Guskiewicz 2000: 46). A number of elements relating to postural sway were measured in the frontal plane from a single-leg stance position in order to discriminate between injured and uninjured ankles (Riemann and Guskiewicz 2000: 46). According to Riemann and Guskiewicz (2000: 47), sway analysis in the frontal plane such as in this study provides the most sensitivity in terms of sway measurement. Difficulties associated with the maintenance of balance following ankle injury would most likely involve the subtalar joint, thus, as asserted by Riemann and Guskiewicz (2000: 47) increased sway movements would mainly be found in the frontal plane (Riemann and Guskiewicz 2000: 47). Cornwall and Murrall (1991) supported this postulation as they found an increased postural sway in individuals with ankle injuries.

In a study performed by Guskiewicz and Perrin (1996a: 327) postural sway in subjects with injured and uninjured ankles under two different treatment conditions (with and without orthotic ankle support) was assessed. This study revealed that injured subjects swayed more than uninjured subjects (Guskiewicz and Perrin 1996a: 330). Furthermore, the use of orthotics provided increased support to the ankles and prevented undesirable motion of the ankle (Guskiewicz and Perrin 1996a: 327). This promoted joint proprioceptor sensitivity leading to the detection of postural sway and thus greater structural support and balance (Guskiewicz and Perrin 1996a: 327). Guskiewicz and Perrin (1996a: 327) used a very small sample size in their investigation (a total of twenty-five participants). A larger sample size would provide greater strength to Guskiewicz and Perrin’s findings.

2.3.3.2 Knee Injury and Balance

Boerboom, Huizinga and Kaan *et al.* (2008: 610) state that the skin, muscles, tendons, menisci, capsule and ligaments of the knee have a number of sensory receptors including proprioceptors and tactile sense organs. When there is damage to the ACL such as a rupture there will be a loss of normal proprioceptive function (Rehm, Llopis-Miro and Turner 1998: 201) including a loss of joint position sense and the detection of movement (Lephart, Pincivero and Rozzi 1998: 152) leading to a loss of stability of the knee and poor balance.

Beard *et al.* (1993: 314) found that reflex protective action of the muscles surrounding the knee was diminished following rupture of the ACL. This is most likely due to a loss of the proprioceptive function of the ACL (Beard *et al.* 1993: 314).

Studies on the effects of ACL rupture on balance using force plate technology have however shown mixed results. As explained by Riemann and Guskiewicz (2000: 48), there are a couple of reasons for this incongruity. Firstly, greater strength in the muscles adjacent to the knee may compensate for poor proprioceptive functioning of the knee after injury (Riemann and Guskiewicz 2000: 48). Secondly, as pointed out by Riemann and Guskiewicz (2000: 48) there may be a failure to discriminate between injured and uninjured knees in a balance assessment due to the normal functioning of the joint mechanoreceptors. As indicated by Lephart, Pincivero and Rozzi (1998: 152), studies have shown that joint mechanoreceptors only provide information to the CNS at the end range of motion. Thus, when considering an LOS assessment, mechanoreceptors of the knee will only provide information to the CNS when the COG passes the LOS boundary, thus it will only be determined at this point whether the mechanoreceptors are functioning normally or not (Riemann and Guskiewicz 2000: 48). Hence, dynamic tests that challenge the postural control system more (such as testing the LOS in a number of directions) would cause an increased recruitment of mechanoreceptors thus more likely to enable one to differentiate between injured and uninjured knees (Riemann and Guskiewicz 2000: 48). Essentially, an injury to the lower extremity will hinder normal proprioceptive function hence affect an individual's ability to balance (Riemann and Guskiewicz 2000: 49). Balance is especially important in soccer due to the constant changes in body position.

2.3.4 Balance and Body Mass Index

Greve, Alonso and Bordini *et al.* (2007: 717) evaluated the correlation between Body Mass Index (BMI) and postural balance. This study was performed with the use of the Biodex Balance System and involved males between the ages of 20 and 40 with a mean BMI of 23.3 kg/m^2 (Greve *et al.* 2007: 717). Anteroposterior stability, lateral stability and general stability indexes of each participant were calculated to determine balance. According to Greve *et al.* (2007: 719), the study revealed a positive relationship between a higher BMI and poor balance and hence balance will worsen with an increase in BMI. This is most likely due to a greater body weight causing an increased amount of stress to be placed on the joints therefore providing potential for proprioceptor damage. Voight and Blackburn (2002 cited in Greve *et al.* 2007: 719) further mention that when there is an increase in body mass, the body's ability to make appropriate postural adjustments in order to maintain balance is weakened.

2.3.5 Balance Assessment

According to Riemann and Guskiewicz (2000: 42), the balance control system is extremely complex and this tends to make the analysis of balance and the problems thereof difficult to understand. As a result of this complexity, there are a number of ways to evaluate balance in both static and dynamic stance (Riemann and Guskiewicz 2000: 42). As asserted by Riemann and Guskiewicz (2000: 42), measurements of balance can be either of qualitative or quantitative nature. Qualitative evaluation involves the use of questionnaires and the like, while quantitative evaluation involves devices such as the force plate for measuring balance (Riemann and Guskiewicz 2000: 42). This study involves the assessment of balance with the use of the Biodex Biosway Portable Balance System and the correlation of these results with questionnaires.

2.3.5.1 Balance Measurement Systems/Instruments

A number of studies assessing balance and postural sway have been done. These have involved the measurement of balance and postural sway during bilateral stance (Lepers, Bigard and Diard *et al.* 1997: 55; Nardone, Tarantola and Giordano *et al.* 1997: 309 and Nardone, Tarantola and Galante *et al.* 1998: 920), during unipedal stance (Tropp, Ekstrand and Gillquist 1984 cited in Waterman, Sole and Hale 2004: 201 and McGuine, Greene and Best *et al.* 2000 cited in Waterman, Sole and Hale 2004: 201), and during stance on movable platforms (Lepers *et al.* 1997: 55 and Rowe, Wright and Nyland *et al.* 1999 cited in Waterman, Sole and Hale 2004: 201). A number of devices have been used to assess balance including the Neurocom Balance Master (Neurocom International) (McGuine *et al.* 2000 cited in Waterman, Sole and Hale 2004: 201); the Biodex Biosway Balance System (Biodex Medical Systems) (Rowe *et al.* 1999 cited in Waterman, Sole and Hale 2004: 201); the Equitest (Neurocom International) (Lepers *et al.* 1997: 56), and Kistler Force Plates (Nardone *et al.* 1997: 310 and Nardone *et al.* 1998: 920).

Tropp *et al.* (1984 cited in Waterman, Sole and Hale 2004: 201) assessed postural sway in male soccer players using a Force Plate. This study revealed that postural sway values of a pathological nature imply a greater potential risk for future ankle injuries (Tropp *et al.* 1984 cited in Waterman, Sole and Hale 2004: 201). Tropp *et al*. (1984) did not include female soccer players in their study which provides limitations to its validity as both genders should be compared before making general conclusions.

McGuine *et al.* (2000 cited in Waterman, Sole and Hale 2004: 201) evaluated the postural sway of male basketball players during unipedal stance. This assessment was performed prior to the start of the basketball season, and measurement was achieved through the use of the Neurocom Balance Master (Neurocom International). Following the study, McGuine *et al.* (2000 cited in Waterman, Sole and Hale 2004: 201) identified that poor balance is a risk factor for ankle injury in basketball. McGuine *et al*. (2000 cited in Waterman, Sole and Hale 2004: 201) did not include postural sway evaluation during bipedal stance which would provide greater viability to the study as basketball is generally played with individuals in bipedal stance.

Waterman, Sole and Hale (2004: 201) performed a randomized controlled trial study evaluating balance limitations including postural sway before and after a netball game. The female participants who were aged between fifteen and twenty-nine years were tested with the Neurocom Balance Master (Neurocom International) (Waterman, Sole and Hale 2004: 202). Waterman, Sole and Hale (2004: 203) assert that linear regression analysis was performed to assess whether changes in balance was related to the time since past injury, perceived recovery of injury, grade of injury, and netball position played. Waterman, Sole and Hale (2004: 206) found that balance may be negatively affected in a netball game, and the alterations in balance were more specific to each individual. Furthermore, the negative changes in balance were not predicted by time since past injury and apparent recovery of injury (Waterman, Sole and Hale 2004: 206). This can relate to soccer as soccer also involves jumping, running and landing activity. Waterman, Sole and Hale (2004: 201) used a very small sample size in their investigation (a total of twenty-seven participants). A larger sample size would provide greater strength to Waterman, Sole and Hale's findings.

As proposed by Goldie, Bach and Evans (1989 cited in Waterman, Sole and Hale 2004: 200), there is no external measure with which the validity of balance measurements can be compared, therefore it is difficult to measure or test correctly which would provide potential for error.

2.3.5.2 Biodex Biosway Portable Balance System

The Biodex Biosway Portable Balance System (BBPBS) is a versatile balance evaluation, rehabilitation and exercising device (Biodex Medical Systems: 1.1) and is used to test postural control (Sherafat, Salavati and Takamjani *et al.* 2013: 113). Essentially, the BBPBS provides reliable, valid and repeatable objective measurements of an individual's somatosensory, visual and vestibular contribution to their neuromuscular control (Lephart, Pincivero and Rozzi 1998: 152) as well as their ability to balance on both stable (static) or unstable (dynamic) surfaces (Biodex Medical Systems: 1.1). It therefore provides information about the individual’s ability to control their COG hence balance; and functions also as a rehabilitation tool (Biodex Medical Systems: 1.1). The BBPBS has a number of strain gauges that determine variations in the amount of pressure exerted by the participant’s feet on the platform (Biodex Medical Systems: A1). According to Cachupe *et al.* (2001: 97), the BBPBS is a reliable instrument for measuring and hence assessing balance indices.

Cachupe *et al.* (2001: 97) found that in their study involving twenty active adults (male n=10, female n=10), the BBPBS provided the following measures of reliability: overall Stability index = 0.94; anterior posterior stability index = 0.95 and medial lateral stability index = 0.93. This test was repeated and it was found that reliability values of overall stability index = 0.90; anterior posterior stability index = 0.86; and medial lateral stability index = 0.76 (Cachupe *et al.* 2001: 103). Thus, this study supported the notion that the BBPBS provided reliable results (Cachupe *et al.* 2001: 106). Furthermore, according Sherafat, Salavati and Takamjani *et al.* (2013: 111), the BBPBS stability indices are reliable measures of postural control and hence balance.

Arnold and Schmitz (1998: 323) assessed the normal patterns and relationships of stability using the BBPBS. Nineteen subjects with no history of injury to the lower extremity participated in this study (Arnold and Schmitz 1998: 324). On evaluation of the overall stability index, anterior-posterior stability index and medial-lateral stability index, it was found that the overall stability index is closely associated with the anterior-posterior stability index (Arnold and Schmitz 1998: 325). It was further revealed that medial-lateral stability contributes to a much lesser degree to overall stability (Arnold and Schmitz 1998: 326). Ultimately, it may be of greater significance to assess anterior-posterior stability and medial-lateral stability alone as a result of the greater influence of anterior-posterior stability on overall stability (Arnold and Schmitz 1998: 326).

As proposed by Sturnieks, Arnold and Lord (2011: 1), postural sway is measured as an indicator of balance and the control of balance. According to the Merriam-Webster Online Dictionary (2013), sway refers to a slow 'oscillating' movement of the body. Postural stability is understood to be the ability of an individual to keep the vertical projection of their COG within their base of support (Paillard 2012: 163) and in so doing counteract the oscillating movement of the body or unsteadiness (Fransson, Gomez and Patel *et al.* 2007: 82). The brain will interpret information received from the proprioceptive, visual and vestibular systems and coordinated nervous signals will be sent to the appropriate muscles so corrective actions to maintain balance are carried out (Lephart, Pincivero and Rozzi 1998: 151, Kejonen 2002: 15). As mentioned by Chaudhry, Findley and Quigley *et al.* (2004: 713), postural stability is a fundamental component in the assessment of balance and the improvement thereof.

The BBPBS measures the participant's postural control, postural stability as well as their sway angle and direction from the COG. (Biodex Medical Systems: 4.5). This is called the stability index – i.e. the average position of the individual from the centre. The stability index does not indicate how much the participant swayed – it only measures their position (Biodex Medical Systems: 4.5.). In order to evaluate the amount that the participant swayed – one measures the standard deviation of the stability index, this is called the Sway Index (Biodex Medical Systems: 4.5). According to Emery (2003: 496), when the postural sway value (sway index) exceeds the postural control value (stability index) it is more indicative of injury – and risk of future injury. Thus, the higher the sway index, the more unsteady the individual is.

Figure 2.3 Biodex Biosway Portable Balance System (Athletico Physical Therapy 2013)

2.3.5.3 Biodex Biosway Portable Balance System Testing Programmes

Postural sway and limitations of stability were measured with the use of two specific testing programmes on the BBPBS. These programs included the Modified Clinical Test for Sensory Integration and Balance (MCTSIB) and the Limits of Stability Test (LOS).

2.3.5.3.1 Modified Clinical Test for Sensory Integration and Balance

During the MCTSIB, the sway index of each participant was measured. This helped to determine the extent to which the participant swayed and hence their degree of postural control or steadiness.

The MCTSIB represented a measurement of static balance in a number of conditions which involved standing on a firm and soft foam surface with eyes open and with eyes closed. Static balance refers to the ability to keep an upright posture and to maintain the COG within the base of support (Figura, Cama and Capranica *et al.* 1991 cited in Rival, Ceyte and Olivier 2005: 133). The MCTSIB involves assessment of participant's static balance with eyes open and closed. Essentially soccer is played with eyes open thus the assessments involving the eyes of the participant being open would be seen as most relevant. However, by involving assessments with eyes closed a better understanding of the somatosensory input to the participant's balance is created as vision is prevented from contributing to balance control. According to Fransson *et al.* (2007: 81), the use of a soft foam surface on a balance platform is the most sensitive way to detect poor balance ability.

The normative data for the BBPBS reliability and clinical test for sensory integration and balance (CTSIB) were measured through the assessment of a random sample of 100 participants (Biodex Medical Systems: B1). All participants had no known abnormalities (Biodex Medical Systems: B1). All testing was performed on site with the approval of the Institutional Review Board (IRB) (Biodex Medical Systems: B1). Testing included the CTSIB test, the Timed Get up and Go test (TUG) and the Gait Speed assessment (Biodex Medical Systems: B1). The TUG test and the Gait speed assessment were included in testing the BBPBS reliability as these tests have already been accepted as reliable means of measuring balance hence would strengthen the BBPBS CTSIB results when a positive correlation is made between these three forms of balance assessment (Biodex Medical Systems: B1).

Following the testing, the Intra-class Correlation Coefficient (ICC) for reliability of the BBPBS was at .81 which is satisfactory (Biodex Medical Systems: B1). The CTSIB Normative Sway Index ranges were calculated to be 0.21-0.48 for eyes open firm surface; 0.48-0.99 for eyes closed firm surface; 0.46-0.88 for visual conflict firm surface; 0.38-0.71 for eyes open soft foam surface; 1.07-2.22 for eyes closed soft foam surface; and 0.84-1.47 for visual conflict soft foam surface (Biodex Medical Systems: B1). As this study included the MCTSIB assessment, both conditions involving visual conflict were eliminated.

CTSIB Normative Sway Index ranges were thus measured as being:

Eyes open/Firm surface:	0.21 - 0.48
Eyes closed/Firm surface:	0.48 - 0.99
Eyes open/Soft Foam surface:	0.38 - 0.71
Eyes closed/Soft Foam surface:	1.07 - 2.22

(Biodex Medical Systems: B1).

The sway index is calculated by working out the standard deviation of the stability index (Biodex Medical Systems: 4.5). The higher the sway index measurement result, the more unstable the participant is during the assessment (Nichols 1997: 557).

The MCTSIB objective is to measure the ability of the participant to maintain a stable upright posture while standing on a fixed platform that is not moving (Biodex Medical Systems: A1). The participant is instructed to keep as stable as possible while under certain sensory conditions (eyes open/closed, static surface (firm) / dynamic surface (soft foam) (Biodex Medical Systems: A1).

As is instructed in the BBPBS Manual (Biodex Medical Systems: D3) the participant will normally produce higher sway index scores on the dynamic surface as opposed to the static surface. If the sway index scores are significantly higher on the dynamic surface, the participant most probably has either a musculoskeletal condition or a sensory condition (which could still be a possibility if they have not been previously diagnosed).

2.3.5.3.2 Limits of Stability Test

The Limits of Stability (LOS) for standing balance test is a fair marker of the amount of postural control an individual has within their sway envelope (Biodex Medical Systems: 4.4). The sway envelope refers to the area that an individual can move their COG within their base of support (BOS) without falling (Biodex Medical Systems: 6.4). Furthermore, limits of stability also refers to 'the ability to initiate voluntary weight shifting to different spatial positions within the base of support without losing (ones) stability' (Gyllensten, Hui-Chan and Tsang 2010: 215).

The sway envelope is estimated to be 8 degrees from the vertical in both left and right directions (16 degrees of sway), 8 degrees forward and 4 degrees backward (Biodex Medical Systems: 6.4). The LOS test represents a measurement of dynamic balance. Figure 2.4 reveals the relationship between LOS, sway envelope and the COG.

In image (A) the cone shaped object represents the LOS that an individual's body moves through while their feet are fixed to a central point on the ground (Nolan, 2009). Image (B) indicates that when the COG is aligned in the centre, the sway envelope (represented by the smaller cone) remains within the LOS (Hall and Brody 2005 cited Nolan 2009: 49). Image (C) indicates that when the COG is disturbed i.e. when the individual is leaning in a specific direction, the sway envelope will exceed the LOS, and a compensatory balance strategy such as the ankle strategy will be used in order for the individual to regain their balance (Hall and Brody 2005 cited in Nolan 2009: 49).

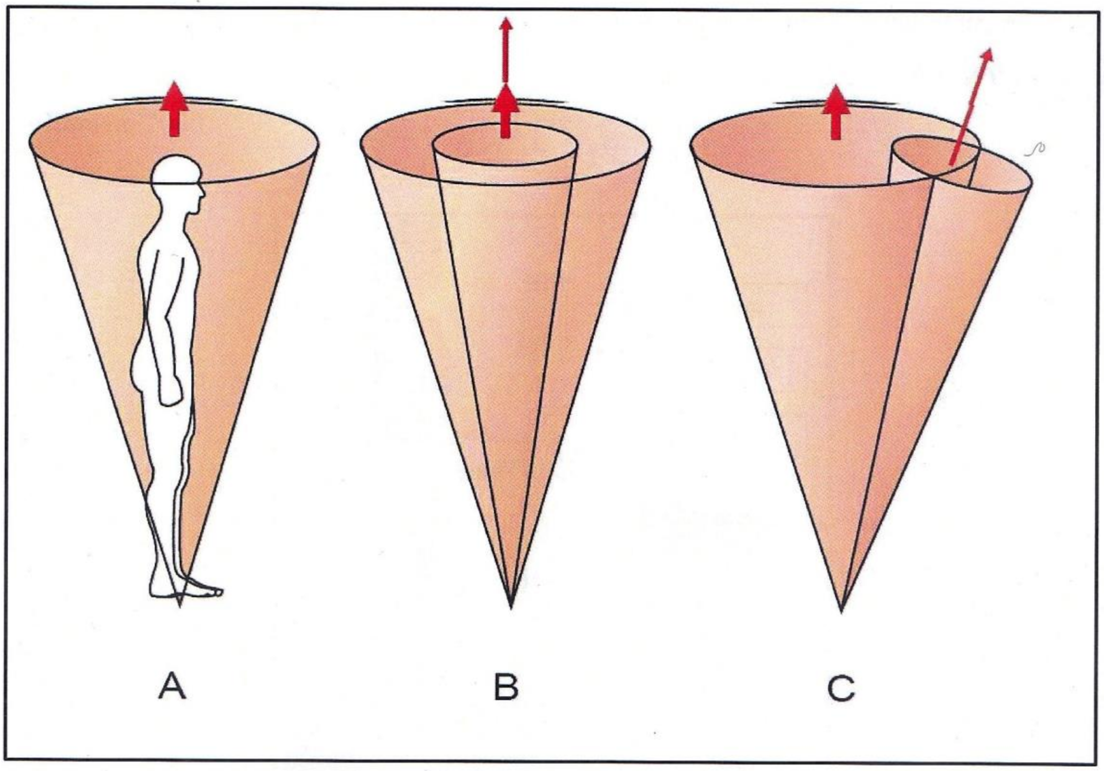

Figure 2.4 Relationship between LOS, Sway Envelope and Centre of Gravity (Hall and Brody 2005 cited in Nolan 2009: 48).

The researcher or instructor is able to calculate with the LOS test in which direction the individual has more trouble controlling their stability (Biodex Medical Systems: 6.4). The individual's score is established based on their capability to move the display cursor to a blinking target and back to the centre of the screen again by shifting their weight on the platform (Biodex Medical Systems: 4.3). The more undeviating the individual's path to the target and back is the higher and more favourable the score will be (Biodex Medical Systems: 8.2).

Poor control and increased time when doing this test may indicate reduced strength of the lower extremity – which could be as a result of current or previous injury, and / or proprioceptive, vestibular, or visual abnormalities or deficiencies (Biodex Medical Systems: 4.3).

2.4 Objectives and the Related Hypotheses of the Study

Objective One

The first objective was to determine the body mass index of adolescent female soccer players.

Null Hypothesis One

The body mass index of adolescent females as investigated in this study is not similar to other studies involving the same population.

Objective Two

The second objective was to determine the prevalence of injury in adolescent female soccer players.

Null Hypothesis Two

Soccer injury prevalence as investigated in this study is not similar to other studies involving the same population.

Objective Three

The third objective was to determine static balance as revealed by the Sway Index (SI).

Null Hypothesis Three

Static balance as determined by the Sway Index of an individual is not affected by injury.

Objective Four

The fourth objective was to determine dynamic balance as revealed by the Limits of Stability (LOS).

Null Hypothesis Four

Dynamic balance as determined by the limits of stability of an individual is not affected by injury.

Objective Five

The fifth objective was to correlate Body Mass Index to Sway Index and Limits of Stability.

Null Hypothesis Five

There is no correlation between Body Mass Index, Sway Index and Limits of Stability.

2.5 Review Conclusion

Injury has a negative effect on an individual's balance. This study aims to clarify this relationship in the female adolescent population as measured by the BBPBS. The BBPBS provides a valuable objective assessment of somatosensory input and neuromuscular control which is vital to balance (Biodex Medical Systems: 1.1).

Chapter Three
Methodology

3.0 Introduction

The aim of this investigation was to determine the relationship between static and dynamic balance and injury in adolescent female soccer players. This chapter includes the detailed research methodology and data collection process. The statistical analysis is also discussed in this chapter.

3.1 Study Design

This study was a cross sectional quantitative survey with measurements. Based on the above study design the research was approved by the Faculty of Health Sciences Research Committee and the Institutional Research Ethics Committee (IREC) (Appendix A) indicating that the research protocol satisfied the ethical requirements set out by the Institutional Research Ethics Committee, Durban University of Technology as well as the Declaration of Helsinki of 1975 (Carlson, Boyd and Webb 2004: 696). The research was also supported by the KwaZulu-Natal Department of Education (Appendix B).

3.2 Setting, Population and Sampling

3.2.1 Setting

This study was conducted in the eThekwini district of KwaZulu-Natal.

The eThekwini district is one of eleven districts in KwaZulu-Natal. Other districts include Amajuba, Zululand, uMkhanyakude, uThungulu, uMzinyathi, Uthukela, uMgungundlovu, iLembe, Ugu and Sisonke (KwaZulu-Natal Department of Education 2011: 29).

The eThekwini district is divided into two sub-districts namely Pinetown and Umlazi. The Pinetown sub-district is divided into four Circuits namely, Ghandi, Mafukuzela, Hammarsdale and Umhlathuze. The Umlazi sub-district is divided into four Circuits namely, Umbumbulu, Phumelela, Chatsworth and Durban Central (KwaZulu-Natal Department of Education 2011: 29).

3.2.2 Population and Sampling

To arrive at the population of soccer playing females who met the inclusion criteria, multi-stage sampling was used. Multi-stage sampling is a sampling method where the sampling units at each stage are sub-sampled from the larger units chosen at the previous stage and is particularly appropriate in large survey based studies (Stafford, Reinecke and Kaminski *et al.* (2006: 353).

Multistage sampling as used in this study is described below:

First Stage: Selection of districts

The eThekwini district was chosen by convenience (Cortinhas and Black 2012: 820) to allow access with minimal cost. The population of schools that offer soccer to female learners in the eThekwini district was identified. The two sub-districts namely, Pinetown and Umlazi of the eThekwini district were both included in the study.

Second Stage: Selection of circuits

Each educational sub-district serves four educational circuits. One circuit was conveniently chosen from each sub-district. The Umhlathuze circuit (City of Durban) was chosen from the Pinetown sub-district and Durban Central circuit from the Umlazi sub-district. Convenience sampling was used to allow accessibility of the schools in the two circuits to the researcher, and to reduce petrol costs as the researcher covered his own transport costs.

Third Stage: Selection of schools

The Umhlathuze circuit (City of Durban) serves approximately forty-five high schools with ten offering soccer to female learners (KwaZulu-Natal Department of Education 2010). The Central Durban circuit has approximately sixty-two high schools with seventeen offering soccer to female learners (KwaZulu-Natal Department of Education 2010). To be included, schools had to offer secondary education and be of a public nature. Half of the eThekwini district population of high schools which offer soccer to females were randomly sampled. In this study, three schools represented the Umhlathuze circuit (City of Durban) from the Pinetown sub-district, and four schools represented the Central Durban circuit from the Umlazi sub-district. Four of the schools used in this study were co-educational and three of the schools were for females only.

Fourth Stage: Selection of females playing soccer

Eighty female soccer players from the initial two-hundred learners who met the inclusion criteria from seven selected schools were included for participation. The sample size was determined by stratified sampling (Daniel 2010: 12).

Inclusion and Exclusion Criteria

Inclusion Criteria

- Only female participants between fourteen to nineteen years of age were accepted for the study.

- All participants had to have played soccer in the previous season.

- Only participants whose parents/guardians (if below eighteen) had signed the Letter of Informed Consent (Appendix D) were included in the study.

- Only participants, who signed the Letter of Informed Consent (if over eighteen) (Appendix E) and assent with (if below eighteen) (Appendix F) were included in the study.

Exclusion Criteria

- Pregnant learners and those suspecting that they may be pregnant were excluded from the study because of the ability to obscure or change the balance measurements related to the study (Oliveira, Vieira and Macedo *et al*. 2009: 27).

- Participants who had any form of systemic, neurological, vestibular, or vascular disease that may affect their balance and stability were excluded from the study.

- Participants who suffered from vertigo or had benign positional vertigo were excluded from the study.

- Participants who recently had surgery were excluded from the study.

- Participants, who had suffered from severe trauma - the extent of which made them unable to participate fully in the study.

All female soccer players meeting the inclusion criteria from within the selected schools were invited to participate in the demographic profile, injury profile and prevalence study (conducted by a different researcher but linked to this study) (Appendix G). It was estimated that a greater than seventy percent response rate in the first study would be attained using the data collection process outlined below. This would equate to a sample size of approximately fifty percent of the total population of female soccer players in the region. The sample size for the survey required a ninety-five percent confidence level which was 197-200 as suggested by the statistician (Singh 2013).

Stratified sampling using the Statgraphics Centurion (2013) computer software programme was used in order to determine the possible sample size for the balance study based on a population of two-hundred. Stratified sampling is the process where the population is divided into subgroups before sampling (Cortinhas and Black 2012: 827). At a ninety-five percent level of confidence with a desired tolerance of 0.20, the required sample size was eighty. Soccer players were invited to participate and if the total number of players who were willing to participate was low, then additional players from the lists would be invited to participate to account for attrition. To meet the sample size of 80 as per the initial design, all female soccer players from seven schools were included. A deviation from the initial plan was necessary since the estimated sample size was not achieved because of a range of factors including: players younger than eighteen years of age forgetting to request permission from their parents/ guardians to participate in their study and / or parents/ guardians not signing the necessary forms; players not arriving for appointments, and often the number of players participating in soccer at some schools was less than twenty. In order to make up the sample size of eighty, a further twelve participants were recruited by convenience sampling from the original random sample, to make up the sample size. It did not affect the original sampling procedure.

3.3 Instrumentation

All participants' demographic as well as injury data were collected by a fellow researcher using a validated questionnaire (Appendix G). The balance variables including Sway Index (SI) and limits of stability (LOS) were measured using the Biodex Biosway Portable Balance System (BBPBS) (Biodex Medical Systems Inc., 20 Ramsey Road, Shirley, New York 11967-4704, USA), and the body mass index (BMI) of each participant was calculated from the measurements of mass and height using a Safeway electronic bathroom scale (Safeway, Model No. EB9003, Clicks Group Ltd., Searle Street, Cape Town, 8001, South Africa) which was calibrated and a stadiometer height measure. As stated in the Merriam-Webster Online Dictionary (2013), a stadiometer is an apparatus which consists of an upright vertical ruler and a sliding horizontal bar which is placed on the wall and can be pulled down to the top of a person's head in order to measure their height. As mentioned in Chapter Two, the BBPBS provided objective measurements of each participant's somatosensory, visual and vestibular contribution to their postural control (Lephart, Pincivero and Rozzi 1998: 152) through their ability to balance on both stable (static) and unstable (dynamic) surfaces (Biodex Medical Systems: 1.1).

The BBPBS platform has a number of sensitive strain gauges under the platform that determine variations in the pressure exerted by the feet on the platform which provides information about the participant's static and dynamic balance ability (Biodex Medical Systems: A1) (Figure 3.1). SI scores represented the participant's static balance ability and LOS direction control scores represented the participant's dynamic balance ability. The foot placement of each participant depended on their height. The majority of participants were in the height category of 1.51m – 1.66m which meant that the central aspect of the posterior heel would be at D6 (left foot) and D16 (right foot). Both feet were angled at 10 degrees (parallel to the tape stuck on the platform). For the individuals below 1.51m the exact foot placement changed to E7 and E15 (Figure 3.2).

Figure 3.1 Biodex Biosway Portable Balance System Platform and Screen (Biodex 2013)

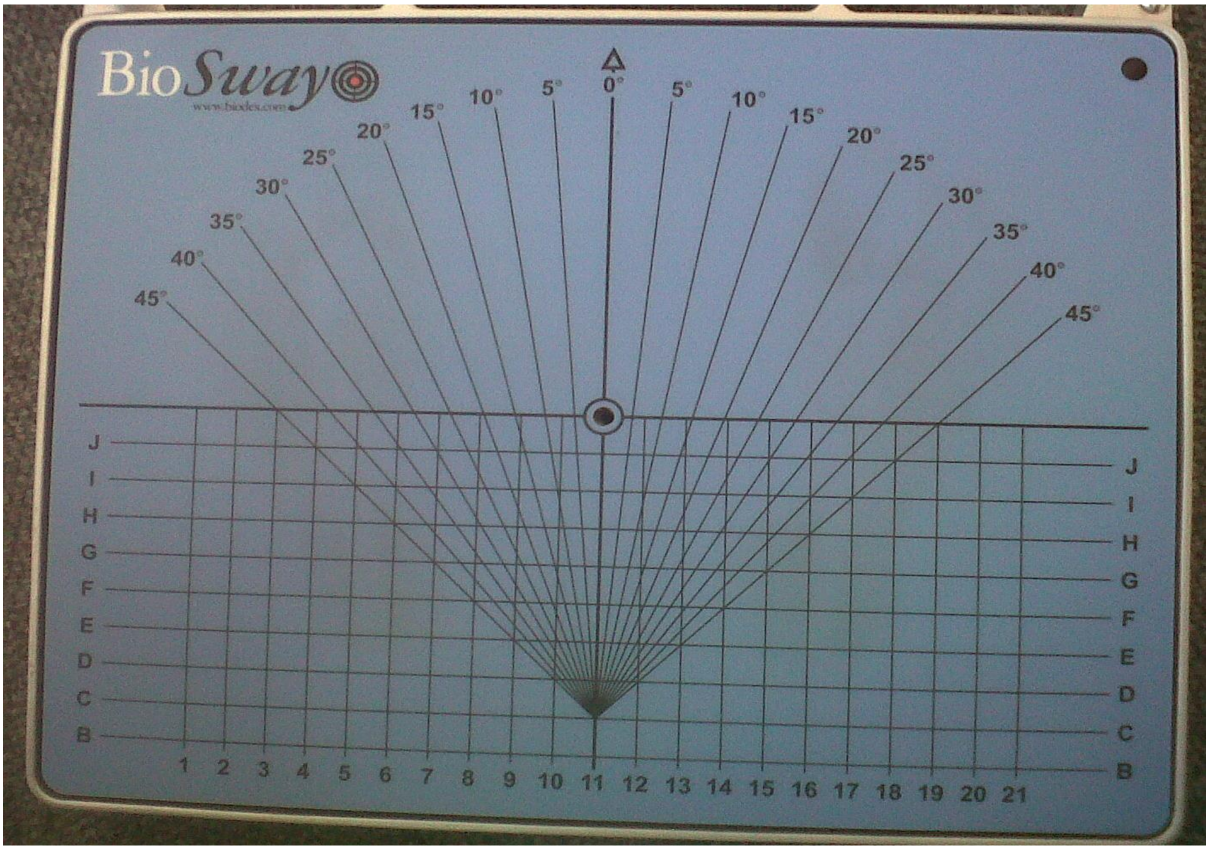

Figure 3.2 Biodex Biosway Portable Balance System Firm Platform (Koenig 2013)

In Chapter Two it was highlighted that the Modified Clinical Test for Sensory Integration and Balance (MCTSIB) represented the analysis of static balance. During the MCTSIB test the SI of each participant was measured. The SI score or the amount that the participant swayed was determined by calculating the standard deviation of the stability index – which refers to the participant's position on the platform (Biodex Medical Systems: 4.5) while standing still with eyes open and closed on both firm (Figure 3.2) and soft foam surfaces (Figure 3.3). The higher the sway index score, the more unstable the participant (Cachupe *et al.* 2001: 102).

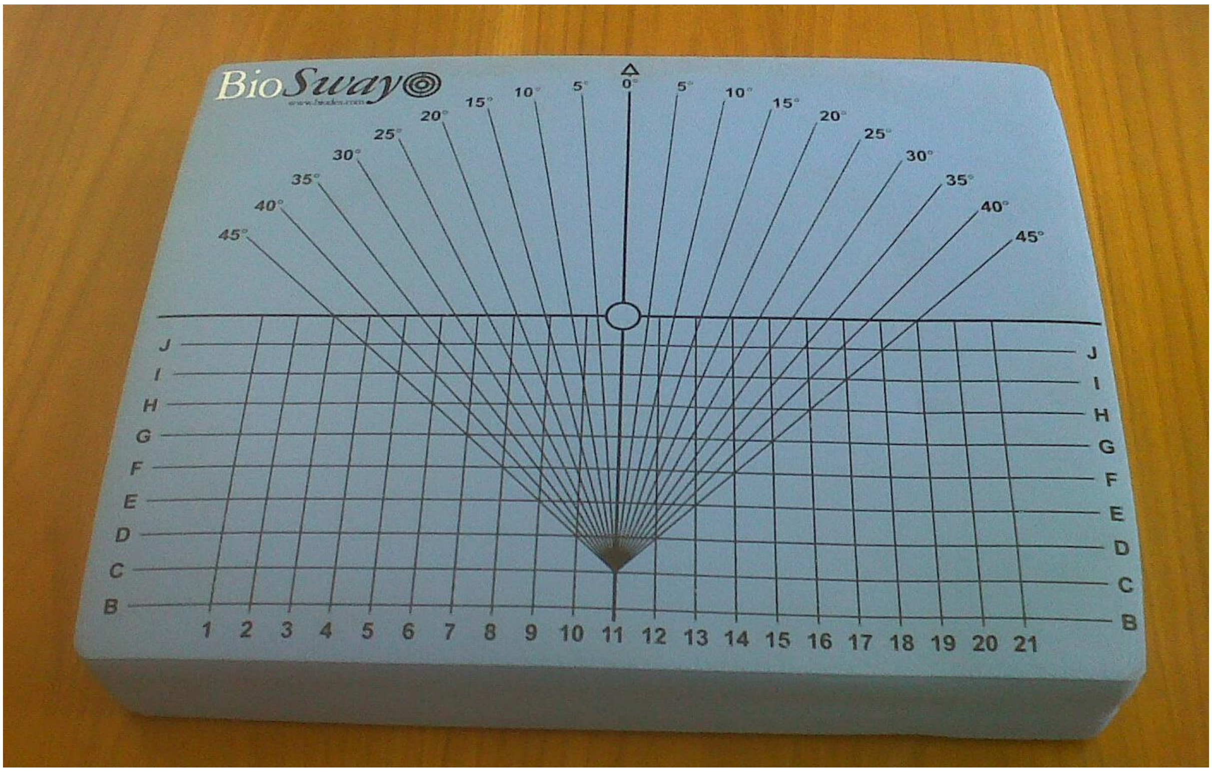

Figure 3.3 Biodex Biosway Portable Balance System Soft Foam Padded Surface (Koenig 2013)

The LOS test represented the analysis of dynamic balance. During the LOS test the amount of postural control each participant had within their sway envelope was measured (Biodex Medical Systems: 4.4). The LOS score was determined based on the participant's capability to move a display cursor from a centre target (central yellow ball in Figure 3.4) to a blinking target (outer yellow balls in Figure 3.4) and back to the centre target of the screen again by shifting their weight while keeping their feet fixed to the platform (Biodex Medical Systems: 4.3). There were eight targets in different positions around the centre of the screen. The more undeviating the individual's path to the target and back to the centre of the screen was, the higher and more favourable the score (Biodex Medical Systems: 8.2). The higher the LOS score, the better the participant's postural control (Figure 3.4).

Figure 3.4 Screen Display During LOS Test (Biodex Medical Systems 2013)

Data from the MCTSIB and LOS test were recorded and stored for later analysis.

Validity and reliability of measurement was controlled using the following measures: The BBPBS was always placed on completely level ground with the use of a builder's level which is a device used to assess whether the surface is even (South African Oxford School Dictionary 2004: 259). This ensured that the system was always stable. The Safeway electronic bathroom scale was also placed on level ground and the stadiometer was placed on the wall above level ground. The wall on which the stadiometer was placed was also assessed by a builder's level. The researcher explained to the participants exactly as to what each balance assessment programme entailed. Before commencing the actual balance testing programme each participant was instructed to stand in the anatomical position (Figure 3.5), keep their feet flat on the platform for the duration of the assessment and not communicate at all. If a participant deviated from these instructions, the participant would start the test from the beginning.

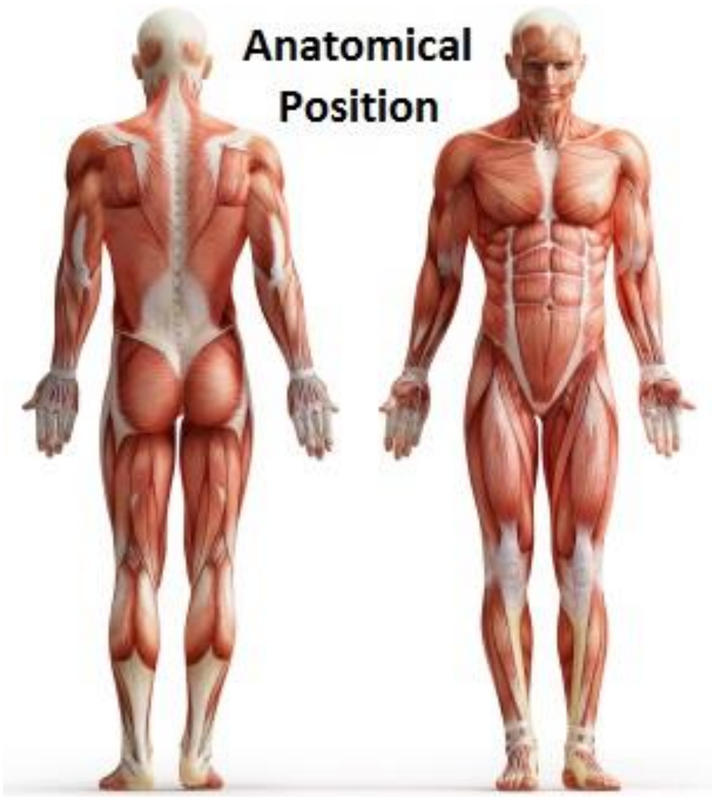

Figure 3.5 Anatomical Position (Wahid 2013)

3.4 Validity and reliability of the Biodex Biosway Portable Balance System

There are a number of studies evaluating the reliability of the BBPBS in the young and elderly populations including studies done by Schmitz and Arnold (1998 cited in Sherafat *et al.* 2013: 116), Hinman (2000 cited in Sherafat *et al.* 2013: 112), Cachupe *et al.* (2001: 97) and Sherafat *et al.* (2013: 117).

As mentioned in Chapter Two, the study performed by Cachupe *et al.* (2001: 97) included two separate assessments of stability index and involved twenty active adults (male *n* = 10, female *n* = 10) and twenty-seven male college athletes (*n* = 27). The BBPBS provided the following mean stability index results after testing the twenty adults: overall Stability index = 0.94; anterior posterior stability index = 0.95 and medial lateral stability index = 0.93 (Cachupe *et al.* 2001: 103). This test then was repeated and reliability values for overall stability index was 0.90; anterior posterior stability index was 0.86; and medial lateral stability index was

0.76 (Cachupe *et al.* 2001: 97). Regarding the twenty-seven male college athletes, it was found that reliability values for overall stability index was 0.92; anterior posterior stability index was 0.89; and medial lateral stability index was 0.93 (Cachupe *et al.* 2001: 97).

Furthermore, according to Hinman (2000 cited in Sherafat *et al.* 2013: 116), the test-retest reliability of the stability indices produced by the BBPBS is comparable to other balance measures and is acceptable for testing of a clinical nature. Hinman (2000 cited in Sherafat *et al.* 2013: 116) assessed the reliability of the BBPBS using the MCTSIB with fifty adults between 18 and 65 years of age. Hinman (2000 cited in Sherafat *et al.* 2013: 116) conveyed that the intraclass correlation coefficient (ICC) value was 0.49 with eyes open and 0.83 with eyes closed. Salvati *et al.* (2009 cited in Sherafat *et al.* 2013: 116) concurred with this in that they found that the ICC value was 0.84 with eyes open and 0.91 with eyes closed. In a study performed by Sherafat *et al.* (2013: 111), the reliability of the BBPBS was evaluated in individuals with low back pain (*n* = 15) and healthy individuals (*n* = 15). The results of this study revealed that the BBPBS provided reliable results especially in the MCTSIB assessments involving eyes closed (Sherafat *et al.* 2013: 111).

These studies provide evidence that the BBPBS provides reliable results. Due to the consistency of results in these studies it is also safe to say that this system provides consistency and hence validity.

3.5 Procedure

After ethics approval from the Durban University of Technology Institutional Research Ethics Committee to conduct the study was received, the KwaZulu-Natal Department of Education (KZN DOE) was approached for permission to conduct the study as the study involved school learners in their jurisdiction (Appendix H). Once approval from the KZN DOE was obtained (Appendix B), school principals in the selected districts (Umlazi and Pinetown) were approached and permission was sought in order to access the learners (Appendix C). Once permission was granted by the principals, the researcher contacted the Sports co-ordinators and soccer coaches of each school. Scheduled times of meeting with the learners who participated in soccer were arranged with the Sports co-ordinators and soccer coaches with an emphasis on not interrupting the academic programme.

The study was conducted in sessions: the first of which was a short information session at the school in which the researcher and fellow researcher spoke to the female soccer players about each research study and the need for it to be done. A question/answer session followed and the researchers stressed the importance of consent to participate in the study. Each researcher then handed out participant information letters (Appendix H), parental information letters (Appendix I), parental consent forms (Appendix D), learner consent forms (Appendix E) and learner assent forms (Appendix F) as appropriate. The learners were requested to obtain parent or guardian permission and to return the signed forms at the next session. The learners were also informed about the data collection schedule and that only learners whose parents had given permission and had themselves signed Informed Consent forms (if over eighteen years) or assents (if under eighteen years) would be allowed to participate in the study. This first session took approximately fifteen to thirty minutes of the soccer players' time.

The second session included the data collection which involved the participants filling in the questionnaire provided by the fellow researcher (Appendix G) and then being tested on the BBPBS. As the balance assessment required a number of days to be completed due to the sample size of eighty participants, not all participants were tested in the same data collection session. These sessions were scheduled at suitable times for the participants. The researcher was available at all times during the day for testing. All schools had appropriate facilities for testing. The different aspects of data collection were conducted through a number of stations through which each participant passed. The stations are described below.

Station 1

Here each participant was requested to hand in their personal assent/consent forms and parental consent forms to the fellow researcher, which was checked. If successful, the participant moved on to the next station.

Station 2

Here the participant was required to fill in a questionnaire presented by the fellow researcher (Appendix G). The fellow researcher explained to all participants how the questionnaire was to be filled in and both researchers were available for the participants should they have any questions. Each questionnaire was numbered from JP01 to JP80 and had a post-it note attached to it. Each number represented a code that was to be entered into the Biosway database. Each code functioned as a means to correlate each questionnaire with the balance test done by the individual filling in the questionnaire. Each participant was instructed to write their name on the post-it which was later removed in order to protect their identity.

Once the questionnaire was completed, participants moved on to the third station. Here the researcher checked all forms which included parental consent, learner consent and learner assent (Appendices D, E and F respectively). As only one participant was allowed to be tested at a time (at the third station), each participant was given a personal appointment time for the third station. This was agreed upon by the participant and the sports co-ordinator/soccer coach. This was quite difficult as participants often did not arrive on time for their appointments and sometimes did not arrive at all. These participants were eliminated from the study due to non-compliance with the original sample being made up through the recruitment of additional participants.

Station 3

The researcher was at each school an hour before commencing the balance testing for that day. This enabled the researcher to have enough time to set up the Biodex Biosway Balance system and other elements associated with the testing procedure such as placing the instructional posters up on the walls (Appendices K and L). The researcher also used a builder's level in order to assess where the floor was most level for the placement of the Biodex Biosway machine, the placement of the scale and the placement of the stadiometer. The builder's level was also used on the wall where the stadiometer was placed.

Before entering the third station, the participant was required to have previously changed into their sports kit (namely a t-shirt and shorts (O'Connell, George and Stock 1998: 138) and removed their socks and shoes. Each participant was required to remove all valuables including cellphones, keys, jewellery, wallets and other objects from their pockets and bodies and to switch off all electronic devices as these devices may have provided disturbance to the testing procedure. The participant's valuables, school bags and clothes were placed in a locked trunk inside the testing room for the duration of the session for security purposes. The researcher kept the key at all times. Once in the testing room (Station 3) the participant's questionnaire was viewed in order to check their code and also to check that the correct participant was being tested by confirming their name (which was written on the post-it note). Once this information was clarified the post-it note was removed.

The participant's height and mass were measured for later calculation of their BMI. Each participant then wiped their feet with the towel provided to remove all debris as dirt particles may provide tactile stimulus interference (Four clean towels were brought everyday to the testing location). Thereafter they were requested to stand on the BBPBS platform. The researcher instructed the participant on the exact standing position.

Once the participant's feet were placed appropriately, the balance testing commenced. The tests included the Limits of Stability (LOS) for standing balance test and the Modified Clinical Test of Sensory Integration and Balance (MCTSIB).

The LOS test involved:

- Each participant stood on the BBPBS platform. The participant was instructed to move a display cursor from a centre target (central yellow ball in Figure 3.4) to a blinking target (outer yellow balls in Figure 3.4) and back to the centre target of the screen again by shifting their weight while keeping their feet fixed to the platform (Biodex Medical Systems: 4.3). There were eight targets in different positions around the centre of the screen.

For the MCTSIB test the participant first:

- stood on the BBPBS platform for 30 seconds with eyes open.
- followed by a period of 30 seconds with eyes closed. This eliminated visual input, therefore only evaluating vestibular and somatosensory inputs (Biodex Medical Systems: C.5). Recordings were taken by the researcher and stored in the BBPBS database. Access to these records required the knowledge of an access code.

A soft foam pad was then placed on the BBPBS platform, on which the participant stood for the next part of the test (30 seconds for each part of the test). Data were collected **with the eyes open to assess** somatosensory interaction with visual input (Biodex Medical Systems: 4.4) **and with the eyes closed to assess** somatosensory interaction with vestibular input (Biodex Medical Systems: 4.4). Recordings were taken by the researcher and were again stored in the BBPBS database. Access to all records on the BBPBS required an access code. At each of the aforementioned points, the researcher took a number of readings which were stored on the Biosway database. All the appropriate information was captured into the participant information sheet (Appendix J). Only the researcher and the research supervisor had access to all collected data (in order to ensure participant confidentiality). This was achieved through only recording the participant’s reference code (JP 01 to JP 80), age, height, weight, body mass index and school’s name (Appendix J). It was also recorded that the appropriate consent forms had been signed. The balance testing (including height and weight assessments) procedure took about 15 minutes per participant and coaches and players were informed of this prior to assessments.

Despite the study involving seven different measurement locations (school halls, classrooms, gymnasiums and sports field pavilion), it was ensured that everything that could be controlled was controlled and kept as consistent as possible for all eighty participants. This involved the testing order: height followed by mass followed by standing on the towel and wiping the feet of any debris followed by standing on the BBPBS. Other elements that provided consistency was the dress code, the procedure order, unpacking and re-packing the BBPBS in exactly the same order each time and only allowing the fellow researcher and a maximum of two participants in the testing room at all times.

3.6 Data analysis

Calculations and processing of data

The “sway index” score of the participant was calculated following the MCTSIB test and ranked on a scale of low to high scores. The higher the score, the more unsteady the individual (Biodex Medical Systems: D1). If the individual fell or had to have support at any time during the test, the score was noted as “fell” (Biodex Medical Systems: D1). The limitations of stability of the individual were calculated based on the Limits of Stability test measurements as described in Chapter Two. These results were correlated with the results from the questionnaire.

Statistical Analysis

All readings obtained from the BBPBS were captured on an excel spreadsheet and submitted to a statistician for analysis. Data were analysed by the statistician using the statistical software SPSS version 21.0.

Statistical analysis included descriptive statistics using frequency and cross-tabulation tables and bar charts. Inferential statistics using Pearson’s correlations (Cortinhas and Black 2012: 489) at a significance level of 0.05 was also incorporated. The testing of the hypotheses was performed using Fisher’s Exact tests (Daniel 2010: 629) for nominal data and ordinal data at a level of significance of 0.05. The statistical analysis also included Mantel-Haenszel Common Odds Ratios (Daniel 2010: 643).

Chapter Four
Results

4.0 Introduction

This chapter presents the results of the study. It will be presented using the following categories:

Participation rate; participant demographics; injury prevalence; balance data, comparisons and correlations. Each objective will be included in its appropriate section to ease the flow of information.

The body mass index of adolescent female soccer players.

The prevalence of injury in adolescent female soccer players.

Static balance as revealed by the sway index (SI).

Dynamic stability as revealed by the limits of stability (LOS).

The relationship between body mass index and sway index and limits of stability.

4.1 Participation Rate

Eighty high school learners were invited to participate in the study. Of the original list of 80 participants, 12 participants (15%) were eliminated from the study due to non-compliance leaving a total of 68 participants (85%). The original sample was made up through the recruitment of an additional 12 participants who met the inclusion criteria, bringing the final participation rate to 100%.

4.2 Participant Demographics

4.2.1 Age

The participants ranged in age from 14 to 18 years of age (mean ±SD = 15.7 ± 1.2 years). The details by age are provided in Table 4.1.

4.2.2 Ethnicity

Participants represented Black, White, Coloured and Indian ethnic groups. The details of participation by ethnicity are shown in Table 4.1. More than half of the participants were Black and a quarter were White.

Table 4.1 Number and percentage of participants by Age and Ethnicity

		Number of Participants	Percentage (%)
Age	14 years	15	18.75
	15 years	23	28.75
	16 years	22	27.5
	17 years	13	16.25
	18 years	7	8.75
Total		80	100
Ethnicity	Black	46	57.5
	White	20	25
	Coloured	13	16.25
	Indian	1	1.25
Total		80	100

4.3 Body Mass Index

Objective One: *To determine the body mass index of adolescent female soccer players*

Just over two-thirds (67.5%) of the participants were of normal weight as they fell within the 18.5 – 24.99 kg/m^2. More than one fifth of the participants were overweight making up 22% of the uninjured and 23% of the injured groups. Injured and uninjured group mean and standard deviations were 23.54±3.56 kg/m^2 and 23.00±4.63 kg/m^2 respectively (Figure 4.1).

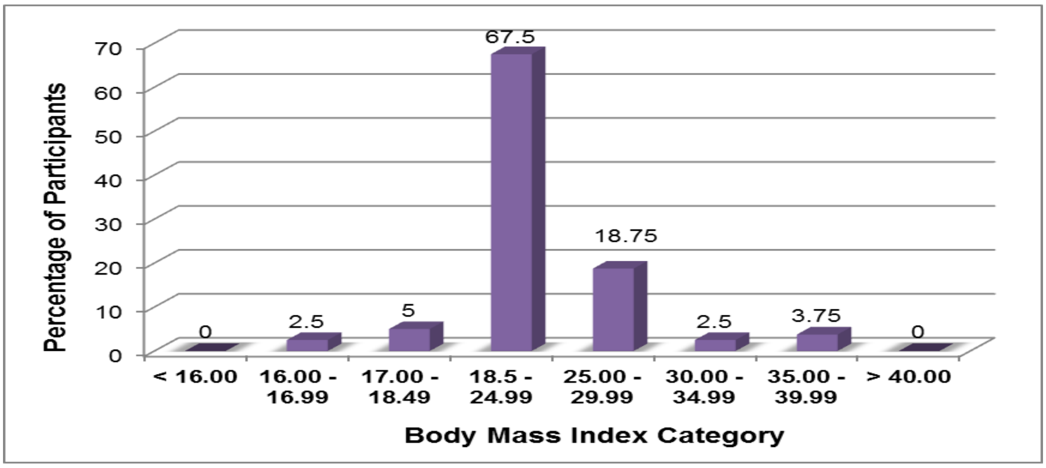

Figure 4.1 Participant Body Mass Index

4.4 Injury Prevalence (Point Prevalence)

Objective Two: ***To determine the prevalence of injury in adolescent female soccer players***

4.4.1 Number of Injuries

Just over a quarter of the participants (27.5%) sustained one or more injuries when playing soccer as seen in Table 4.2. The majority of the participants who sustained injuries reported just one injury (16%) (Table 4.2).

Table 4.2 Prevalence of Soccer Injury

Injured	Number of Injuries	Number of Participants	% of Participants	Total Number Not Injured and Injured	%
Not Injured	0	58	72.5	58	72.5
Injured	1	13	16.25	22	27.5
	2	6	7.5		
	3	1	1.25		
	4	2	2.5		
Total		80	100	80	100

4.4.2 Type of Injury

The most common type of injury was classified as a "muscle injury". This was reported by 16 participants and made up 72.7% of injuries (Figure 4.2).

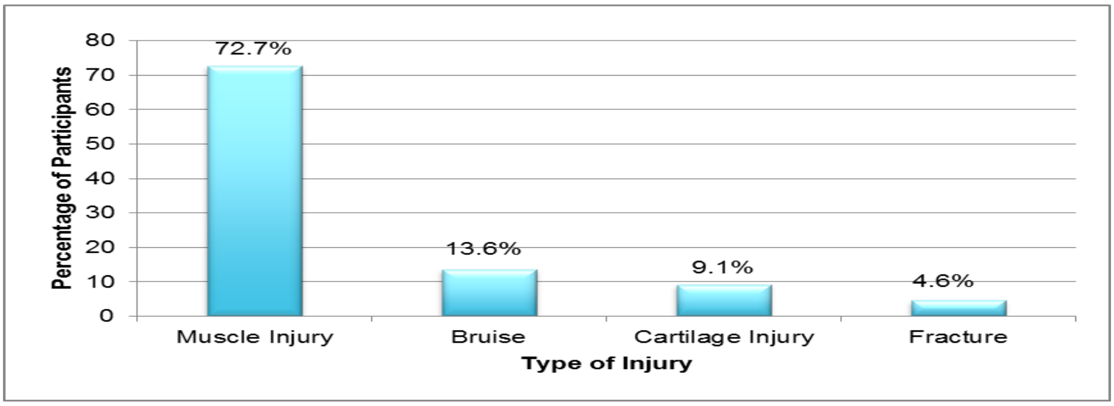

Figure 4.2 Percentage of participants who sustained the different types of Injury (*n* = 22)

4.4.3 Part(s) of the Body Injured

The ankle and knee were the most commonly injured parts of the body. These injuries were reported by six participants with each body part making up 27.3% of injuries respectively (Figure 4.3).

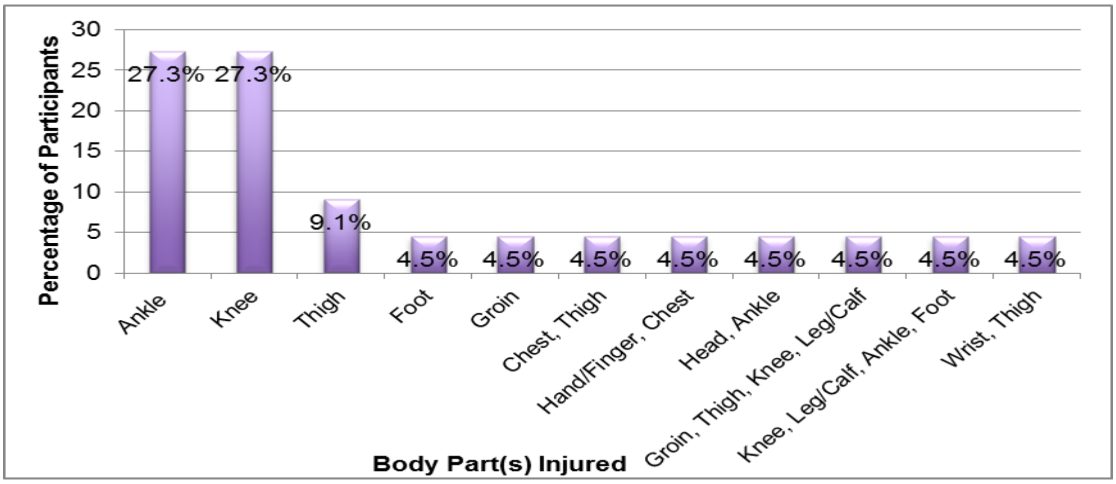

Figure 4.3 Percentage of participants who sustained injuries to specific Part(s) of the body (*n* = 22)

4.4.4 Mechanism of Injury

The most common mechanism of injury was running (22.7%) followed by collision with a player (18.2%) and tackle (13.6%) (Figure 4.4).

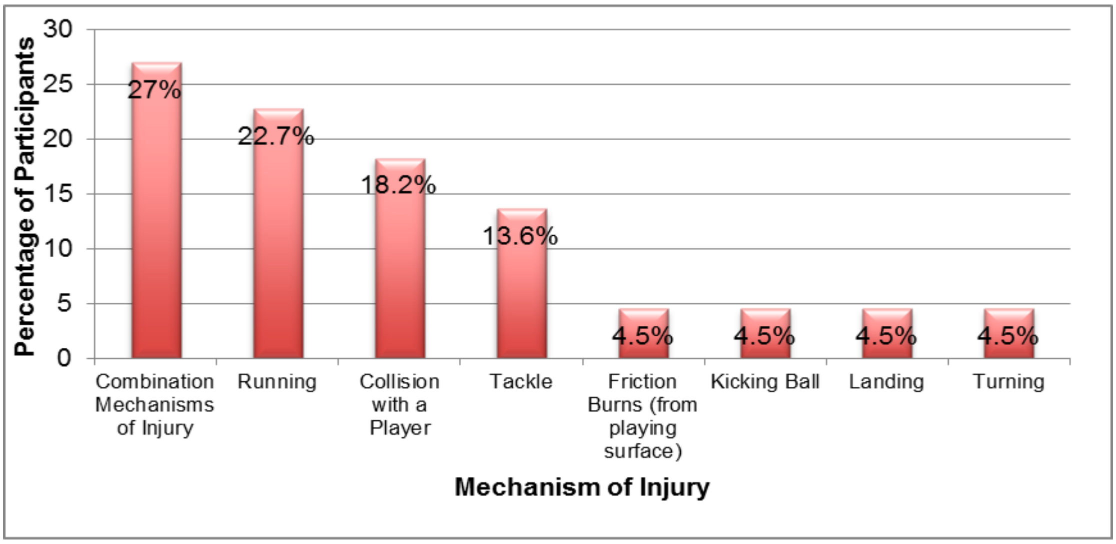

Figure 4.4 Percentage of participants reporting different mechanisms of Injury (*n* = 22)

Combination mechanisms made up the largest proportion of mechanisms reported, as shown in Figure 4.4.There were six combination mechanisms of injury each of which affected 4.5% of the sample. The combinations of injury mechanisms included landing/running/collision with a player, running/overuse, tackle/collision with a player, tackle/landing/running, tackle/overuse/kicking ball and tackle/turning/collision with a player/kicking ball.

4.5 Balance Data

4.5.1 Static Balance

Objective Three: To determine static balance as revealed by the Sway Index (SI)

Static balance was determined by Sway Index (SI) value. The static balance of each participant was calculated during the four assessments of the SI in the Modified Clinical Test for Sensory Integration and Balance (MCTSIB). These four assessments involved each participant standing on a firm surface with eyes open, standing on a firm surface with eyes closed, standing on a soft foam surface with eyes open and standing on a soft foam surface with eyes closed.

Sway Index with Eyes Open and Closed on Firm and Soft Foam Surfaces

Figure 4.5 shows the mean SI for the injured and uninjured participants for each of the four SI assessments.

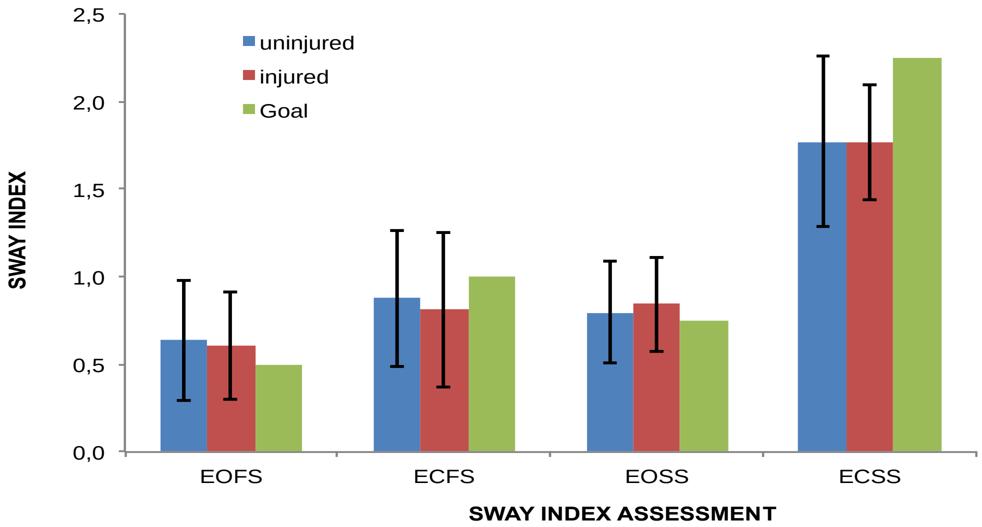

Figure 4.5 Mean and standard deviation for Sway Index under each of the Sway Index Assessments.

Goal for each assessment is included in green. The error bars represent standard deviation.

Figure 4.5 shows no significant differences between the means of the injured and uninjured participants under each of the different SI assessments and with the goal. For SI, mean values below the goal suggest good balance. For assessments with eyes closed, SI in both injured and uninjured participants suggest an acceptable static balance. It was noted that the SI assessments involving participants standing with eyes open on a soft surface was slightly higher for the injured as opposed to the uninjured.

Table 4.3 Number of participants (%) with good and poor SI scores by condition, Mantel-Haenszel Common Odds Ratio Estimate, Confidence Intervals (CI) and *p* values.

SI: EOFS				OR M-H estimate	CI	Asymp. Sig. (2-sided)
Static Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)			
Good	23 (28.8)	10 (12.5)	33 (41.25)	0.789	0.293-2.123	0.638
Poor	35 (43.8)	12 (15.0)	47 (58.75)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
SI: ECFS						
Static Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)			
Good	42 (52.5)	20 (25)	62 (77.5)	0.263	0.055-1.254	0.094
Poor	16 (20.0)	2 (2.5)	18 (22.5)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
SI: EOSS						
Static Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)			
Good	29 (36.25)	9 (11.25)	38 (47.5)	1.444	0.535-3.902	0.468
Poor	29 (36.25)	13 (16.25)	42 (52.5)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
SI: ECSS						
Static Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)			
Good	49 (61.25)	19 (23.75)	68 (85.0)	0.860	0.210-3.52	0.833
Poor	9 (11.25)	3 (3.75)	12 (15.0)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			

Good and poor static balance was determined by the SI score that each participant achieved. If the participant achieved a score within the SI range for the condition being tested then they were denoted as having a “good” SI score. If the participant achieved a score higher than the upper limit of the SI range for the condition being tested then they were denoted as having a “poor” SI score.

In Table 4.3 it is shown that a greater number of participants in both the injured and uninjured groups performed poorly in the assessments involving eyes open and either standing on a firm or soft foam surface. A higher percentage of injured participants performed poorly in the assessment involving eyes open and standing on a soft foam surface as opposed to the uninjured participants.

Risk of Injury

The risk estimate for injury is shown in the odds ratio in Table 4.3. It is illustrated that an injured participant with poor SI EOSS is 1.444 times more likely to be injured than an injured participant with good SI in the same condition.

4.5.2 Dynamic Balance

Objective Four: To determine dynamic balance as revealed by the Limits of Stability (LOS)

Dynamic balance was determined by the limits of stability (LOS) test. Participants were challenged to move through a movement pattern consistent with the sway envelope. The sway envelope refers to that area a person can move their COG within their base of support (Biodex Medical Systems: 6.4). The higher the LOS score, the better the dynamic balance control.

Limits of Stability Direction Control

Table 4.4 shows the mean and standard deviation for each of the limits of stability direction control (LOSDC) assessments for both the injured and uninjured. The goal for each assessment as well as significant *p* values is also expressed. The goal score is 65 and above for all conditions except backward direction control which is 30.

Table 4.4 Mean and standard deviation percentage control in each direction for injured and uninjured participants and desired goal and *p* values

LOS Direction Control	Goal	Injured Participants	Uninjured Participants	*p*
Overall	>65	43.54±12.61	43.09±11.49	0.886
Forward	>65	37.66±18.8	40.18±18.33	0.586
Backward	>30	62.62±19.1	67.14±15.08	0.322
Right	>65	63.21±14.17	62.68±15.63	0.886
Left	>65	61.22±13.68	57.46±16.0	0.297
Forward-Right	>65	47.74±14.28	49.14±14.68	0.700
Forward-Left	>65	46.10±14.85	47.09±15.24	0.793
Backward-Right	>65	55.4±14.32	52.18±16.06	0.389
Backward-Left	>65	52.06±14.08	48.64±16.02	0.357

Data in Table 4.4 shows no significant difference between the injured and uninjured participants. Dynamic balance in the backward direction was acceptable for both injured and uninjured participants with the uninjured participants scoring higher than the injured participants.

Table 4.5 Number of participants (%) with good and poor LOS scores by direction control, Mantel-Haenszel Common Odds Ratio Estimate, confidence Intervals (CI) and *p* values.

LOSDC: Overall				OR M-H estimate	CI	Asymp. Sig. (2-sided)
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)			
Good	23 (28.8)	10 (12.5)	33 (41.25)	0.357	0.047-2.707	0.319
Poor	35 (43.8)	12 (15.0)	47 (58.75)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
LOSDC: Forward						
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)			
Good	42 (52.5)	20 (25.0)	62 (77.5)	0.597	0.130-2.744	0.508
Poor	16 (20.0)	2 (2.5)	18 (22.5)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
LOSDC: Backward						
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)			
Good	29 (36.25)	9 (11.25)	38 (47.5)	0.873	0.086-8.869	0.909
Poor	29 (36.25)	13 (16.25)	42 (52.5)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
LOSDC: Right						
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)			
Good	49 (61.25)	19 (23.75)	68 (85.0)	1.348	0.499-3.642	0.556
Poor	9 (11.25)	3 (3.75)	12 (15.0)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			

LOSDC: Left				OR M-H estimate	CI	Asymp. Sig. (2-sided)
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)	1.326	0.482-3.648	0.585
Good	23 (28.8)	10 (12.5)	33 (41.25)			
Poor	35 (43.8)	12 (15.0)	47 (58.75)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
LOSDC: Forward-Right						
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)	1.600	0.312-8.199	0.573
Good	42 (52.5)	20 (25)	62 (77.5)			
Poor	16 (20.0)	2 (2.5)	18 (22.5)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
LOSDC: Forward-Left						
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)	0.597	0.130-2.744	0.508
Good	29 (36.25)	9 (11.25)	38 (47.5)			
Poor	29 (36.25)	13 (16.25)	42 (52.5)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
LOSDC: Backward-Right						
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)	1.789	0.575-5.565	0.315
Good	49 (61.25)	19 (23.75)	68 (85)			
Poor	9 (11.25)	3 (3.75)	12 (15)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			
LOSDC: Backward-Left						
Dynamic Balance	Uninjured No. (%)	Injured No. (%)	Total No. (%)	1.482	0.372-5.912	0.577
Good	49 (61.25)	19 (23.75)	68 (85.0)			
Poor	9 (11.25)	3 (3.75)	12 (15.0)			
Total	58 (72.5)	22 (27.5)	80 (100.0)			

If a participant achieved a score below the “goal” score for the LOSDC being assessed, their score would be denoted as “poor”. If a participant achieved a score at or above the “goal” score for the LOSDC being assessed, their score would be denoted as “good”.

The data highlighted in Table 4.5 showed that the combined injured and uninjured participants performed poorly in all the assessments except backward direction control. A higher relative percentage of injured participants performed poorly in the assessment involving right, left, forward-right, backward-right and backward-left direction control.

Risk of Injury

The risk estimate for injury is shown by the odds ratio in Table 4.5. It is illustrated that injured participants with poor LOS right, left, forward-right, backward-right and backward-left direction control are more likely to be injured than injured participants with good LOS direction control in the same directions.

Time to Complete Limits of Stability Assessment Test

As seen in Figure 4.6, injured participants took less time on average than uninjured participants to complete the LOS test.

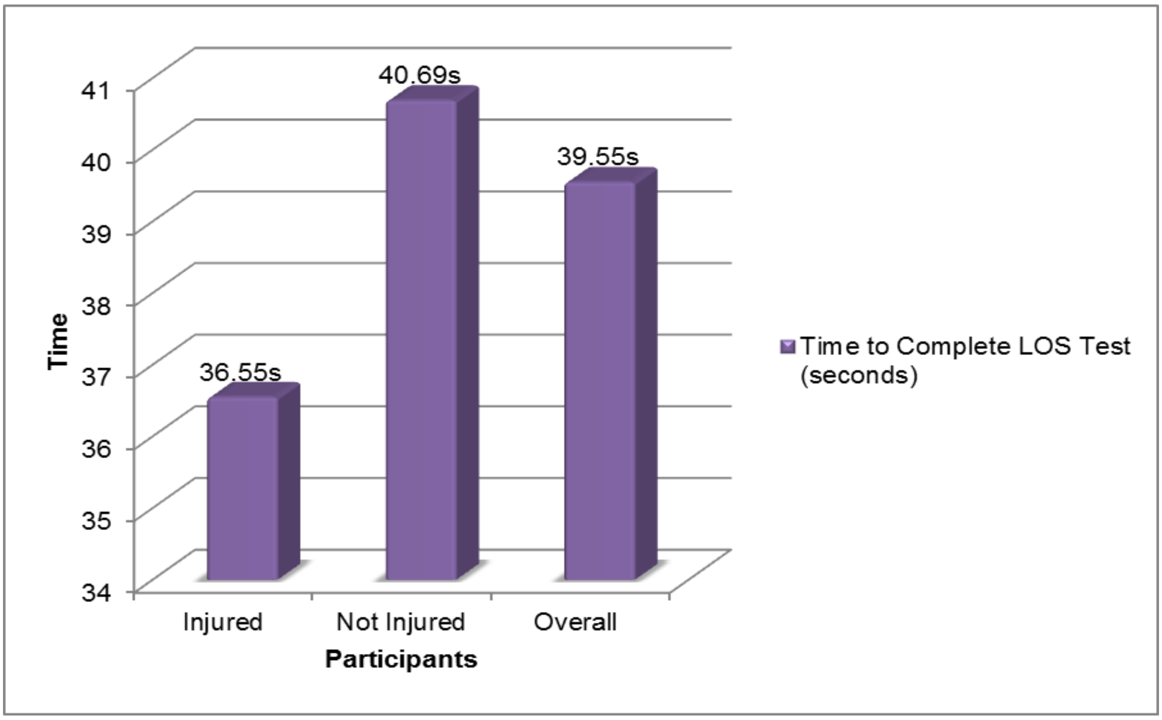

Figure 4.6 The time taken to complete the LOS assessment

4.6 Correlations

4.6.1 Correlation of Body Mass Index to Sway Index Test and Limits of Stability Test

Objective Five: To correlate Body Mass Index to Sway Index and Limits of Stability

Table 4.6 Pearson's Correlation Coefficients and *p* values for BMI and injury vs. SI and LOS.

BMI with	Correlation Coefficients (*R*)	*P* values
injury	0.056	0.62
EOFS	0.219	**0.05**
ECFS	0.213	**0.05**
EOSS	0.267	**0.02**
ECSS	0.232	**0.04**
LOSDC Right	-0.263	**0.02**
Injury with		
EOFS	0.041	0.71
ECFS	0.073	0.52
EOSS	-0.072	0.53
ECSS	0.003	0.98

Pearson's ($p < 0.05$)

Only conditions with significant changes were included except for the correlations with injury. As shown in Table 4.6, significant correlations between BMI and SI were noted. LOS right directional control correlated with BMI. Injury did not correlate with SI. However, despite the significant *p* values exhibited, the *r* values indicated a weak to low degree of correlation.

Chapter Five
Discussion

5.0 Introduction

This chapter discusses the results. This discussion will follow the same sequence as the results chapter.

5.1 Participant Demographics

5.1.1 Age

This study included participants in five age strata of five age groups. This was representative of the five high school grades in South Africa (Grades 8-12) (South African Department of Basic Education 2012: 10). The majority of participants were fifteen and sixteen years old (Table 4.1). This is similar to the study performed by Mtshali *et al.* (2009: 164) who investigated soccer injuries in adolescent females with a mean age of sixteen years.

Emery *et al.* (2005: 182) report that there are a limited number of studies investigating risk factors for injury in youth sport including balance. This study provides beneficial information pertaining to balance and injury in this age category.

5.1.2 Ethnicity

In terms of the South African population as a whole, the ethnic distribution portrayed within this study was not representative of the country. This is similar to Mtshali's *et al.* (2009: 163) study which only included schools in the Johannesburg East District. With regard to the eThekwini population, representation of Africans, Indians, Whites and Coloureds should be at 71%, 19%, 8% and 2% respectively (eThekwini Municipality, 2012). Thus, in terms of the eThekwini population, the ethnic distribution in this study was again not represented. This distribution could be related to participation by ethnicity in school soccer in the selected district, data for which is not available.

5.2 Objective One: To determine the body mass index of adolescent female soccer players

A large percentage of participants (sixty-seven percent) had a Body Mass Index (BMI) which is normal according to the World Health Organisation (2006) statistics. The findings in this study are consistent with the report by Greve *et al.* (2007: 717) who evaluated the correlation between balance and BMI in a population with a mean BMI of 23.3 kg/m^2. Furthermore, this study is also similar to a study performed by Gittelsohn *et al.* (1996: 2996) who found that seventy percent of the females in their study between the ages of ten and nineteen had a normal BMI.

Despite these similarities, this study contrasts with a study performed by Vignerova *et al.* (2007: 420) who found that a high percentage of adolescent females had a low mean BMI. This study also differs from a study performed by Caradas, Lambert and Charlton (2001: 115) who observed that Black South African female adolescents on average had a higher BMI than other ethnic groups. According to Gittelsohn *et al.* (1996: 2991), eating disorders are more common in society today and a larger number of ethnic groups are adopting Western eating habits which could provide reasoning to support Caradas, Lambert and Charlton's (2001: 115) finding. BMI and its relationship with balance within this particular study was assessed and it will be discussed later in this chapter.

5.3 Objective Two: To determine the prevalence of injury in adolescent female soccer players

Injury prevalence included number of injuries, type of injury, parts of the body injured and mechanism of injury. This study included point prevalence as injury data only from the previous season were used as the current season was not completed at the time of data collection.

Approximately twenty-seven percent of the participants in this study were injured as a result of playing soccer. This is similar to the study performed by Mtshali *et al.* (2009: 164) who reported an injury prevalence rate of thirty-three percent in adolescent female soccer players.

As seen in Figure 4.2, muscle injuries (72.7%) were the highest for a single injury followed by bruising (13.6%). This is supported by Lilley, Gass and Locke (2002: 4) who found that strains (35%) accounted for the highest number of injuries to female soccer players (n = 239). According to Smith (2013: 8), a strain refers to injury to the muscle as a result of overstretching, or if severe, as a result of a tear. However, Mtshali *et al.* (2009: 164) found that injuries to the joints were most common in female adolescent soccer players which contrast to the findings in this study. In this study, participants self-diagnosed the type of injury - which could affect the reliability of the anatomical structure which was actually injured. The participant may not have been able to differentiate between muscle injury and a cartilaginous injury for example.

The most common parts of the body that were injured included the ankle and knee (Figure 4.3). This is supported by Mandelbaum and Putukian (1999), Boden, Griffin and Garrett Jr (2000), Ford *et al.* (2005 cited in Mtshali *et al.* 2009) and Mtshali's *et al.* (2009) respective studies. According to Mtshali *et al.* (2009: 166), the ankle has the most contact during soccer matches and training be it with the ball, the ground or other players, thus the ankle will sustain more injuries. Ford *et al.* (2005 cited in Mtshali *et al.* 2009: 166) stated that during cutting meaning movements which are most common in sports such as soccer, females tend to abduct their knee more than males which will lead to an increased genu valgus and resultant injury to the anterior cruciate ligament of the knee. Mandelbaum and Putukian (1999: 259) and Boden, Griffin and Garrett Jr (2000: 2) indicated that knee injuries especially to the anterior cruciate ligament are significantly more common in females than in males.

Muscle injuries and bruising are consistent with the results displayed in Figure 4.4 regarding mechanism of injury. In this study the most common single mechanism of injury was running, followed by a collision with a player and the tackle (tackling or being tackled). Hawkins *et al.* (2001: 45) specified in their study that running was the most common mechanism of injury. In contrast to this, Agel *et al.* (2007: 274) reported that a collision with a player most commonly resulted in injury while Wong and Hong (2005: 475) found that being tackled was the most common cause of injury. Despite the variability in these three mentioned studies, the three aforementioned mechanisms of injury including running, collision with a player and tackling or being tackled were more common in this particular study.

5.4 Objective Three: To determine static balance as revealed by the Sway Index (SI)

The higher the SI the more unstable the participant (Nichols 1997: 557). The static balance of each participant was calculated during the four SI assessments in the Modified Clinical Test for Sensory Integration and Balance (MCTSIB) including eyes open firm and soft surfaces and eyes closed firm and soft foam surfaces. According to Lephart, Pincivero and Rozzi (1998: 150), the visual and somatosensory systems are the main contributors to balance control. In addition to this, Balter *et al.* (2004: 74) suggested that the more elite and highly trained the athlete, the greater the contribution of the vestibular system to balance control. In this study the participants did not fall into the 'highly trained elite athlete' category so this study provided a good indication of the somatosensory and visual contribution to balance.

In a study performed by Sellers (1988: 489) on children, it was found that Black participants had better static balance results than participants of other ethnic groups. This study supports this notion as the majority of participants in this study were Black Africans (57.5%) and most participants performed well in the assessment of static balance. However, despite this correlation between studies, the participants of this study were of a higher age group than the participants in Sellers' (1988: 487) study.

Figure 4.5 illustrates that the mean SI value in the assessment involving eyes open and standing on a soft foam surface was higher for injured participants as opposed to uninjured participants. This is supported by Fransson *et al.* (2007: 81) who found that standing on a soft foam surface provides a greater challenge to an individual, therefore will lead to poor balance assessment results especially if injured. Fransson *et al.* (2007: 84) found in their study that a larger amount of movement of muscles was detected during assessments involving a soft foam surface as opposed to standing on a firm surface. Furthermore, Fransson *et al.* (2007: 84) detected that having eyes open or closed during assessments has a similar effect on the postural sway of the individual due to similar oscillations of the knees in both conditions. However, Fransson *et al.* (2007: 84) also noted that higher oscillations in muscles were found in the hips, shoulders and head with eyes closed which challenges this argument. This study however found that participants whether injured or not injured performed well in the SI assessment involving eyes closed and standing on a soft foam surface which opposes Fransson's *et al.* (2007: 81) findings regarding a soft foam surface providing a greater challenge to an individual's balance.

According to Horak (1987: 1883), when participants stand on a soft foam surface, somatosensory information is actually rendered inaccurate. However, Stillman (2002: 674) disagrees with this statement as when standing on a soft foam surface, information to the CNS from the ankle and foot proprioceptors will be increased.

All participants met the inclusion criteria for this study, hence had no visual and vestibular disorders, thus poor static balance in any of the four SI assessments was in all probability linked to a somatosensory deficit. The results of this study agrees with Lephart *et al.* (1998: 149) who point out that injury especially to the knee and ankle leads to a loss of normal somatosensory function as a result of disruption to the proprioceptors. Hence, this supports the claim that participants would most likely have poor static balance if injured, and hence, have proprioception disruption. Winter (1995: 212) mentions that studies on static balance have illustrated that the ankle muscles including plantarflexors and dosiflexors dominate in promoting balance in an anterior-posterior direction, while hip adductors and abductors promote balance in the medial-lateral direction. Thus, injury to either of these muscles could lead to increased sway. This study concurs with this as the ankle was one of the most common parts of the body injured (Figure 4.3).

The soleus muscle has a large number of muscle spindles (Levy 1963 cited in Fitzpatrick, Rogers and McCloskey 1994: 396). However, Sozzi, Honeine and Do *et al.* (2013: 1183) suggested in their study on the control of body balance that the activity of the soleus muscle is more associated with the support of the body as opposed to balance control. Furthermore, Sozzi *et al.* (2013: 1178) highlighted that the activity of the soleus increased with eyes closed. Thus, injured participants performing well in the SI assessments involving eyes closed would most likely be due to the supportive function of the soleus. Furthermore, in O'Connell, George and Stock's (1998: 140) study it was found that having the eyes closed had no significant effect on postural sway.

Cornwall and Murrall (1991) studied postural sway in individuals with acute ankle sprains and they found that there was a general increase in sway in those injured as opposed to those uninjured. Friden, Zatterstrom and Lindstrand *et al.* (1989 cited in Riemann and Guskiewicz 2000: 46) and Guskiewicz and Perrin (1996a: 343) support this as they also found that there is an increase in postural sway following ankle injury. This study provides similarity to these findings as increased sway was in all likelihood due to ankle injury in the injured participants as the ankle was found to be one of the most commonly injured parts of the body.

Mandelbaum and Putukian (1999: 259) indicated that knee injuries are most common in female soccer players especially that of the ACL. According to Kennedy, Alexander and Hayes (1982 cited in O'Connell, George and Stock 1998: 137) and Guskiewicz and Perrin (1996b: 57), the ACL of the knee provides proprioceptive information to the brain, thus with injury to the knee there will be a negative effect on the stabilising and protective function of the knee in maintaining balance. This will affect sway (O'Connell, George and Stock 1998: 137) and hence static balance. This study provides similarity to these findings as the knee (other than the ankle) was the most commonly injured part of the body.

According to Tropp, Ekstrand and Gillquist (1984 cited in Emery 2005: 191), a deficit in balance provides potential for future injury. This is supported in this study as seen in Table 4.3 in terms of the odds of getting injured, a participant with poor static balance during the assessment involving eyes open and standing on a soft foam surface is more likely to be injured in future. All other sway index assessments did not provide risk of future injury based on poor sway index scores. Regardless of these arguments, there was no significance in the relationships between mean SI scores in injured and uninjured participants (Figure 4.3).

5.5 Objective Four: To determine dynamic balance as revealed by the Limits of Stability (LOS)

Dynamic balance was determined by Limits of Stability (LOS) value. The higher the LOS value the more stable the participant. According to Sell (2011: 6), the assessment of dynamic balance is more of a challenge to the participant than the assessment of static balance. As illustrated in Table 4.4, the mean LOS values in overall, right, left, backward-right and backward-left direction control was lower for injured participants as opposed to uninjured participants. Generally all participants performed poorly in the LOS direction control assessments (Table 4.4) which differs from the study performed by Gyllensten, Hui-Chan and Tsang (2010: 218) on Thai Chi Practitioners where it was found that all participants had superior LOS direction control.

According to Winter (1995: 212), hip adductors and abductors promote balance in the medial-lateral direction which would involve right and left direction control. In a study performed by Hubbard *et al.* (2007 cited in Wikstrom, Naik and Lodha *et al.* 2010: 411), it was found that there is a reduction in hip muscle strength following ankle injury. Furthermore, following ankle dysfunction - be it through injury or instability, there will also be a change in hip biomechanics in relation to dynamic balance (Gribble, Hertel and Denegar 2007 cited in Wikstrom *et al.* 2010: 411). This study supports this in the sense that injured participants (of which the majority had ankle or knee injuries) performed poorly in lateral direction control. Another element in relation to this is that of ankle injury and resultant fatigue and the compromising strategy of the body in order to keep balance. In a study performed by Yaggie and McGregor (2002: 227), it was found that when there is a reduction in the sensitivity of the ankle joint proprioceptors from fatigue, and therefore the ability of the ankle to contribute to postural balance will be compromised. Yaggie and McGregor’s (2002) study on ankle fatigue provided a level of understanding of what would occur with the injured ankle. This is supported by Armstrong, Ogilvie and Schwane (1983 cited in Yaggie and McGregor 2002: 227) in that when a muscle is fatigued it can lead to injury of that muscle and reduced strength. Lundin, Feuerbach and Grabiner (1993 cited in Yaggie and McGregor 2002: 227) indicated that when the larger muscles of the ankle are not able to function due to injury or fatigue, the smaller muscles of the foot will compromise for this and will be unable to provide the stability that the larger muscles usually provide (Ekdahl 1992 cited in Yaggie and McGregor 2002: 227). As it may be quite difficult for the smaller muscles of the foot to provide that stability more proximal muscles may have to be recruited such as the hip muscles in order to promote balance. This will lead to fatigue of these muscles and reduced ability at left and right direction control.

In backward-right and backward-left direction control, the majority of injured participants achieved poor LOS assessment scores (Table 4.5). In a study performed by Kuo and Zajac (1993: 145), it was found that the hamstrings, gluteus maximus, and the quadriceps including the vastus medialis and lateralis were most sensitive in backward leaning despite the hamstrings not normally being sensitive in backward leaning (Kuo and Zajac 1993: 146). As highlighted in the review of the literature, female athletes have a greater average quadriceps activity and as emphasized by Mandelbaum and Putukian (1999: 256) recruit the quadriceps before the hamstrings. As indicated by Gyllensten, Hui-Chan and Tsang (2010: 219), the maximum distance that an individual can lean during an LOS assessment is linked to the proprioceptive functioning of the knee. In this study, the knee was one of the most commonly injured parts of the body and therefore would have resulted in abnormal functioning of the mechanoreceptors of the knee (Riemann and Guskiewicz 2000: 48). Abnormal functioning of the mechanoreceptors of the knee would lead to an interruption of the supply of proprioceptive information to the CNS which in turn would cause a reduction in reflex muscle contraction which promotes stability to the knee (Lephart, Pincivero and Rozzi 1998: 152). The quadriceps converges to form the patella tendon and attach to the tibia - all of which are anatomically associated with the knee (Seeley, Stephens and Tate 1998: 237). Thus, injury to the knee would lead to poor backward directional control as a result of the deficit in sensory input from the damaged mechanoreceptors of the knee and resultant poor reflex muscle activation (Lephart, Pincivero and Rozzi 1998: 153) when leaning backwards.

Injured participants achieved relatively better scores in the forward direction control assessment as opposed to uninjured participants however, all participants generally performed poorly in this particular assessment. This included forward direction control followed by forward-left direction control and forward-right direction control. According to Winter (1995: 208), when an individual leans forward the posterior muscles associated with the hip, knee and ankle joints are more dominant in promoting balance and preventing falling. Moreover, as indicated by Winter (1995: 198), the ankle strategy is the first process recruited in leaning forward followed by the hip strategy. In this study the ankle (along with the knee) was the most commonly injured part of the body. Lephart, Pincivero and Rozzi (1998: 153) point out that damage to the ankle proprioceptors such as the mechanoreceptors following injury can lead to a deficit in postural muscle reflex reaction. Therefore, poor forward direction control resulted. Furthermore, trunk proprioception is mature at sixteen years of age (Miller, Homberger and Coppenrath *et al.* 1992 cited in Cheng, Law and Pan *et al.* 2011: 569) yet only 42 participants in this study were sixteen years old or more (Table 4.1). Riemann and Guskiewicz (2000: 42) indicate that the ankle strategy involves a distal to proximal activation of muscles starting with the muscles associated with the ankle to the more proximal muscles of the hips and back, therefore ankle injury along with immature proprioceptive function of the trunk would be the reasons for poor forward direction control.

Regardless of these arguments, there was no significance in the relationships between mean LOS direction control scores in injured and uninjured participants as seen in Table 4.4.

Another important element to consider is that injured participants took less time on average than uninjured participants to complete the LOS test (Figure 4.6). This could be as a result of the much smaller sample of injured participants. This is in contrast to Gyllensten, Hui-Chan and Tsang's (2010: 218) study where it was found that Tai Chi Practitioners took longer to perform the LOS direction control assessment when compared to healthy controls.

As previously mentioned, Tropp, Ekstrand and Gillquist (1984b cited in Emery 2005: 191) propose that a deficit in balance provides potential for future injury. This is supported in this study as seen in Table 4.5 in terms of the odds of getting injured, participants with poor LOS right, left, forward-right, backward-right and backward-left direction control are more likely to be injured in future.

Despite these arguments, no significant differences were detected, thus the null hypothesis is supported.

5.6 Objective Five: To Correlate Body Mass Index (BMI) to Sway Index (SI) and Limits of Stability (LOS)

In this study, as seen in Figure 4.1, the majority of injured and uninjured participants had a normal BMI. According to McGraw, McClenaghan and Williams *et al.* (2000: 484), a high fat percentage can lead to a loss of balance. Voight and Blackburn (2002 cited in Greve *et al.* 2007: 719) also point out that an increase in body mass negatively affects the body's ability to maintain balance. Individuals with a high BMI will have a poor control of their limits of stability as found by Greve *et al.* (2007: 719) and the selection of ankle, hip and stepping strategies will not be optimal (Ledin and Odkvist 1993 cited in Greve *et al.* 2007: 719).

In this study, the majority of injured participants in the normal BMI category achieved good SI scores in the assessments involving eyes closed and standing on firm and soft foam surfaces. This provides strength to the notion that a normal BMI is not associated with poor balance. In Greve's *et al.* (2007: 719) study it was found that a high BMI is associated with poor balance. Furthermore, in contrast to

Greve's *et al.* (2007: 719) study, most participants performed poorly in the assessment of LOS direction control although most had a normal BMI.

As indicated by Greve *et al.* (2007: 719), the correlation between stability (or balance) and BMI can in a sense be criticised as a result of a greater chance of error. In this study the correlation coefficients between static and dynamic balance assessments and BMI were weak to low (Table 4.6) which lends support to this argument. In the SI assessment involving eyes open and standing on a soft foam surface, the correlation coefficient was higher relative to the other SI assessments (R = 0.267) which could indicate that static balance in this particular condition is more likely to be affected by an increased BMI as opposed to the other conditions, however this still reflects a low degree of correlation.

However, despite the low degree of correlation generally exhibited in the injured, significant relationships existed between all four SI assessments and BMI as well as LOS right direction control and BMI ($p < 0.05$). The injured group had a slightly higher mean BMI than the uninjured group and performed poorly in the SI assessment involving eyes open and standing on a soft foam surface (R = 0.267), so this could support Greve *et al*. (2007: 719) in the sense that an increased BMI is associated with poor balance. However, both groups fell within the normal BMI range.

The significant relationships reflected in this objective rejected the null hypothesis.

5.7 Objectives and the related Hypothesis Revisited

Null Hypothesis One

The body mass index of adolescent females as investigated in this study is not similar to other studies involving the same population.

This was rejected as a number of studies supported the body mass index findings in this study.

Null Hypothesis Two

Soccer injury prevalence as investigated in this study is not similar to other studies involving the same population.

This was rejected as a number of studies supported the injury prevalence findings in this study.

Null Hypothesis Three

Static balance as determined by the Sway Index of an individual is not negatively affected by injury.

This was accepted, as no significant relationships were exhibited.

Null Hypothesis Four

Dynamic balance as determined by the limits of stability of an individual is not negatively affected by injury.

This was accepted, as no significant relationships were exhibited

Null Hypothesis Five

There is no correlation between Body Mass Index and Sway Index and Limits of Stability.

This was rejected, as there were significant relationships between all Sway Index assessments and Body Mass Index as well as Limits of Stability right direction control and Body Mass Index in the injured.

5.7 Summary

This chapter represented a discussion of the results. Chapter 6 will include the conclusion, limitations and recommendations.

Chapter Six
Conclusion, Limitations and Recommendations

6.1 Conclusion

The purpose of this study was to determine the relationship between postural stability, balance, and injury in adolescent female soccer players in the eThekwini District of KwaZulu-Natal. No relationship between static or dynamic balance and injury in adolescent female soccer players was found. However, a relationship between static balance and dynamic balance to the right with BMI was found.

6.2 Limitations and Recommendations

There were a number of limitations in this study and hence there is potential for future studies and therefore the following is recommended:

In this study although participants met the inclusion criteria they had not been physically examined before being tested. Thus, participants could have unknowingly had a number of systemic conditions that would affect their balance. Future studies could possibly assess this limitation and involve prior physical examinations of each participant before having their balance assessed.

Although this study involved going to a number of locations, the testing environment was kept as constant as possible. However, the weather conditions, temperature and humidity could not always be controlled. This was not ideal in terms of the uniformity and consistency of the study. It is suggested that future studies ensure that data collection occurs at one venue.

The ethnic representation in this study did not accurately reflect the eThekwini District and it is suggested that future studies adhere to this. The sample size in this study was 80 and it is suggested that a larger sample is required for future studies so to more accurately assess the relationships studied and therefore reduce statistical error.

This study involved a once-off assessment of participants and it is recommended that future studies include a continuous assessment of participants throughout the season, at the beginning of the season and at the end of the season or the end of the previous season and the end of the current season for accurate comparison.

As the injured participants suffered from a range of injuries it is suggested that future studies involve the assessment of individuals with similar injuries such as ankle or knee injuries in order for there to be accurate assessment of the effects of injury to that particular part of the body and balance.

As time was limited for the participants to complete the questionnaire (provided by the fellow researcher but linked to this study), a number of participants did not complete it satisfactorily which resulted in attrition and subsequent replacement to maintain the sample size. It is suggested that future researchers allow a greater amount of time for the participants to fill in the questionnaire even if it involves two or more sessions.

All injuries were self-diagnosed by participants so it is suggested that future studies involve complete injury assessment and diagnosis prior to testing.

Future studies could be more specific in terms of when participants were injured – whether during matchplay or practice.

It is recommended that studies with similar methodology to this study should be done on male adolescent soccer players in order to provide comparitive conclusions.

Lastly, future studies involving the assessment of BMI in adolescents could be more specific in terms of BMI normative values for each age group in the adolescent population.

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Appendices

Appendix A: IREC Approval Letter

DURBAN UNIVERSITY of TECHNOLOGY

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)

5 February 2013

IREC Reference Number: **REC 90/12**

Mr J-P Koenig
28 Hollander Crescent
Morningside
Durban
4001

Dear Mr Koenig

The relationship between postural stability, sway, balance and injury in adolescent female soccer players in the eThekwini District of KwaZulu Natal

I am pleased to inform you that Full Approval has been granted to your proposal REC 90/12, subject to the following:

- Ethics checklist: No. 2 should be 'no'. This is a non-interventional study. The reference to no-treatment or placebo conditions in this question relates to the protection of participants who have a treatable condition and are not receiving treatment.

The Proposal has been allocated the following Ethical Clearance number IREC 006/13. Please use this number in all communication with this office.

Approval has been granted for a period of one year, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's. In addition, you will be responsible to ensure gatekeeper permission.

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

[redacted]

Dr D F Naude
Chairperson: IREC

Appendix B: DOE Approval Letter

education

Department:
Education
PROVINCE OF KWAZULU-NATAL

Enquiries: Sibusiso Alwar | Tel: 033 341 8610 | Ref.:2/4/8/382

Mr J-P Koening
New Guilderland Sugar Estate
Private bag X10610
STANGER
4450

Dear Mr Koening

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct a pilot and research entitled: **THE RELATIONSHIP BETWEEN POSTURAL STABILITY, SWAY, BALANCE AND INJURY IN ADOLESCENT FEMALE SOCCER PLAYERS IN THE ETHEKWINI DISTRICT OF KZN,** in the KwaZulu-Natal Department of Education Institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from 01 April 2013 to 30 April 2015.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Mr. Alwar at the contact numbers below.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report / dissertation / thesis must be submitted to the research office of the Department. Please address it to The Director-Resources Planning, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in Kwazulu Natal Department of Education.

[redacted]

Nkosinathi S.P. Sishi, PhD
Head of Department: Education

18-04-2013
Date

KWAZULU-NATAL DEPARTMENT OF EDUCATION
POSTAL: Private Bag X 9137, Pietermaritzburg, 3200, KwaZulu-Natal, Republic of South Africa
PHYSICAL: Office G25, 188 Pietermaritz Street, Pietermaritzburg, 3201. Tel. 033 3418610 Fax : 033 341 8612
EMAIL ADDRESS: sibusiso.alwar@kzndoe.gov.za; CALL CENTRE: 0860 596 363;
WEBSITE: www.kzneducation.gov.za

...dedicated to service and performance
beyond the call of duty

Appendix C: Principal Information and Permission Letter

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
LETTER OF INFORMATION AND PERMISSION

Dear Principal/Board of Governors

Thank-you for your time.

I am a Chiropractic Masters student at the Durban University of Technology. I am in the process of undertaking a research project and humbly request your assistance/ permission to allow selected learners to participate in my study. My study involves adolescent female soccer players.

Permission to conduct the study has been provided by the KwaZulu-Natal Department of Education and the Institutional Research Ethics Committee at the Durban University of Technology.

Title of the Research Study: The relationship between postural stability, sway, balance, and injury in adolescent female soccer players in the eThekwini District of KwaZulu-Natal.

Researcher: JP Koenig, B. Tech Chiropractic

Supervisor: Prof. T. Puckree, PhD PT.

Brief Introduction and Purpose of the Study: This study will investigate whether there is a relationship between postural stability – or how stable one is when in a standing position, balance and injury in high school female soccer players.

The information gathered will help us to understand a number of things. Firstly, the effect that injury has on balance and stability; secondly to what extent poor balance is a risk factor for injury; and lastly the study will provide greater clarity in terms of the importance of balance training as an addition to a normal soccer training program in order to prevent future injury.

Outline of the Procedures: In order for the learner to be considered for the study, they have to meet the inclusion criteria and if they do not meet these criteria they will not be able to participate.

Inclusion Criteria

- Females between 14-19 years of age.
- All participants had to have played soccer in the previous season.
- Only participants whose parents/guardians (if below 18) had signed the letter of informed consent will be included in the study.
- Only participants, who signed the letter of informed consent (if over 18) and assent with (if below 18) participating will be included in the study.

Exclusion Criteria

- Pregnant learners and those suspecting that they may be pregnant will be excluded from the study because of the ability to obscure or change the measurements related to the study.
- Participants who have any form of systemic, neurological, vestibular, or vascular disease that may affect their balance and stability will be excluded from the study.
- Participants who suffer from vertigo or have benign positional vertigo will be excluded from the study.
- Participants who have recently had surgery will be excluded from the study.
- Participants who have suffered from severe trauma the extent of which will make them unable to participate fully in the study.

According to http://www.rightdiagnosis.com/b/balance/subtypes.htm, types of disorders that may affect balance include peripheral vestibular balance disorder (ear affected), central vestibular balance disorder (brain affected), systemic balance disorder (major body systems affected), vascular balance disorder (blood flow affected), vertigo, and benign positional vertigo.

The procedure of this study will involve two sessions – the first of which will be a short information session in which the researcher will speak to the learners (soccer playing learners between 14 and 19 years) and hand out information forms, consent forms and assent forms. The researcher will explain the whole procedure to the learners, and will underline the importance of consent and assent. There will be a short question/answer session at the end of the session. The learners will be required to take all forms home for their parents/guardians and themselves to sign. The learners will also be told when the next session is and that only those who have consent will be allowed to take part in the study. This first session will take approximately 15 minutes of the learner's time. The second session will be arranged with the principal and will be at a time suitable for everyone.

The second session will involve the learners (participants) moving through a number of stations. This session will be at the school if adequate facilities are available. If not, it will be at the Durban University of Technology and transport will be available for the participants.

STATION 1: Here the participant will be requested to hand in their personal and parental consent forms and assent forms which will be checked. If successful, the participant will move on to the next station.

STATION 2: Here the participant will be required to fill in a questionnaire provided by the fellow researcher.

STATION 3: At this station the participant will be required to take their shoes and socks off and have their height and weight measured. The participant will them be instructed to stand on the Biodex Biosway Balance platform (Biodex Inc.). The researcher will instruct the participant what to do. This will involve the participant standing on the Biosway unit on a firm and foam surface with their eyes open and closed. Each participant's movement pattern will also be assessed.

At each of the aforementioned points, the researcher will take a number of readings on the Biosway computer.

Station 1 and 2 combined should take 30 minutes for the entire group and Station 3 should take 15 minutes per participant.

The Biodex Biosway Portable Balance System is a device used to assess balance and is also used as a training device. It provides valid and reliable objective measures of a participant's neuromuscular control and ability to balance on a firm and/or unstable surface (Biosway Portable Balance System Operation Manual, Biodex Medical Systems Inc., Shirley, New York).

Risks or Discomforts to the Participant: There are no risks or discomforts to the participant.

Benefits: Benefits to the researcher:
This study will create a better understanding of the effect injury has on balance, of whether poor balance is a risk factor for injury, and of the importance of balance training in order to prevent future injury on the playing field.

Benefits for the participant:
This research will benefit the participants directly as information regarding their balance and its role in their injury may be identified. This research will also benefit the participants indirectly as the information gathered will provide incite in relation to poor balance as a risk factor for soccer injury and the potential importance of balance training to prevent injury.

Reason/s why the Participant May Be Withdrawn from the Study: The participant may withdraw at any time from the study should they so wish. Reasons for which the participant may be withdrawn from the study include – non-compliance, illness, and any other unforeseen circumstances. There will be no adverse consequences for the participant should they choose to withdraw.

Confidentiality: The identity of the participant will be protected via a coding system, which will be used for writing up the dissertation and publication. Also, assessment of each participant's balance, stability, height and weight will be performed behind closed doors so it will be completely confidential.

Research-related Injury: Although there is an extremely minimal risk of injury occurring during the research process as it is non-invasive, measures will be taken to ensure participant safety and care. The appropriate school authorities will be notified and the school injury protocol will be followed. The participant's parents/guardians and family doctor (or hospital) will be contacted and all will be done to ensure the injured participant is correctly taken care of.

Persons to Contact in the Event of Any Problems or Queries:
Researcher: JP Koenig (073 191 6896). The Institutional Research Ethics Administrator (031 373 2900). Complaints can be reported to Professor F. Otieno (031 373 2382) or dvctip@dut.ac.za.

Your assistance would be highly appreciated and vital to this research.

Thanking you sincerely
JP Koenig (073 191 6896)
Researcher

Prof. T. Puckree (031 3732704)
Research Supervisor

PERMISSION PROVIDED BY:

Name: ____

Signature: ____

Position: ____

Date: ____

Appendix D: Parental Consent Letter

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
CONSENT

Dear Parent/Guardian.

Statement of Agreement for your child to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, _____________ (name of researcher), about the nature, conduct, benefits and risks of this study – Research Ethics Clearance Number: ____________,
- I have also received, read and understood the above written information (Parent/Guardian Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my Childs sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and Childs participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to allow my child to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my Childs participation will be made available to me.

____________________ _________ ________ _________________________

Full Name of Parent/Guardian **Date** **Time** **Signature/Right Thumbprint**

I, ________________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

________________________ ________________ ____________________

Full Name of Researcher **Date** **Signature**

________________________ _________________ ___________________

Full Name of Witness (If applicable) **Date** **Signature**

Appendix E: Learner Consent Letter

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
CONSENT

Dear Learner.

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, _____________ (name of researcher), about the nature, conduct, benefits and risks of this study – Research Ethics Clearance Number: ____________,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

____________________ _________ ________ _________________________

Full Name of Participant **Date** **Time** **Signature/Right Thumbprint**

I, ________________ (name of researcher) herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

______________________ _______________ ______________________

Full Name of Researcher **Date** **Signature**

______________________________ _____________ ______________________

Full Name of Witness (If applicable) **Date** **Signature**

______________________________ ______________ __________________

Full Name of Legal Guardian (If applicable) **Date** **Signature**

Appendix F: Learner Assent Letter

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
ASSENT

(TO BE COMPLETED BY THE PARTICIPANTS OF THE RESEARCH)

TITLE OF RESEARCH PROJECT: The relationship between postural stability, sway, balance, and injury in adolescent female soccer players in the eThekwini District of KwaZulu-Natal.

SUPERVISOR: Prof T. Puckree (031 3732704)
NAME OF RESEARCHER: JP Koenig (0731916896)

Please circle the appropriate answer **YES /NO**

1. Have you read the research information sheet? Yes No
2. Have you had an opportunity to ask questions about this study? Yes No
3. Are you happy with the answers to your questions? Yes No
4. Have you discussed this study with anyone other than the researcher?
   Yes No
5. Have you received enough information about this study? Yes No
6. Do you understand the implications of your involvement in this study?
   Yes No
7. Do you understand that you are free to?
   a) Withdraw from this study at any time? Yes No
   b) Withdraw from the study at any time, without reasons given
   Yes No
   c) Withdraw from the study at any time without affecting your future

Health care or relationship with any of the stakeholders in this study.

Yes No

8. Do you agree to participate in the study? Yes No

If you have answered NO to any of the above, please obtain the necessary information from the researcher and / or supervisor before signing. Thank You.

Please print in block letters:

Research Participant: ______________________ Signature: ____________________

Witness Name: ___________________________ Signature: ___________________

Researcher's Name: _______________________ Signature: ____________________

Appendix G: Questionnaire

POST-PILOT GROUP:

QUESTIONNAIRE FOR FEMALE HIGH SCHOOL SOCCER PLAYERS IN THE ETHEKWINI DISTRICT

Dear Learner.

Please answer all questions to the best of your ability. Tick the relevant box for each question. All responses are strictly confidential.

PART A: DEMOGRAPHIC PROFILE

How old are you? : 14yrs□ 15yrs□ 16yrs□ 17yrs□ 18yrs□ 19yrs□

What is the name of the sub-district that your school falls under? Pinetown□ Umlazi□

Race: African□ Coloured□ Indian□ White□ (for statistical purpose only)

Other (please specify) ________________________

In which team did you play in the previous season? A□ B□ C□

What age group did you play in? U/15□ U/16□ U/17□ U/18□ U/19□

How many years have you participated in school soccer? ________________

What position did you play?

Goalkeeper (GK) □ Defender (DF) □ Midfielder (MF) □ Striker(S) □

How many soccer matches did you play in during the past season?

1-5□ 6-10□ 11-15□ 16-20□ More than 20 matches□

How many training sessions did you participate in during the past season?

1-5□ 6-10□ 11-15□ 16-20□ More than 20 training sessions□

How many matches did you participate in during the last soccer tournament? 1-4□

5-7□ 9-12□ More than 12 matches□

Do you play any other sport? Yes □ No □

If yes, please specify______________________ and at what level?

Professional□ League□ Club□ Other□(please specify)____________

Do you participate in any sport or non-sport extra-mural activity/activities? Yes□ No□

If yes, please specify____________ (for example: ballet, acrobatics, gymnastics, surfing, trail running etc.)

PART B: INJURY PROFILE

1. **How many injury/injuries do you currently have due to playing soccer?**
   ___________ (if none, please proceed to question 9.)

2. **Which part/s of your body is injured? (You may choose more than 1)**
   Head□ Face□ Neck□ Shoulder□ Elbow□ Wrist□ Hand/Finger□ Chest□ Abdomen□ Back□
   Groin□ Thigh□ Knee□ Leg/Calf□
   Ankle□ Foot□ Other□(please specify) _______________

3. **When did your injury/injuries occur?** A week ago□ 2 weeks ago□
   3 weeks ago□ 4 weeks ago□ More than 4weeks□

4. **Did the injury/injuries occur during:** Match play □ Training□ Both □

5. **How would you describe the injury/injuries?(You may choose more than 1)**
   Cut □ Graze □ Bruise □ Muscle injury □
   Fracture (Broken bone) □ Other □(please specify) _____________

6. **How did you hurt yourself? (Please tick more than 1 if applicable)**
   Tackle □ Turning□ Landing□ Running□
   Heading the ball □ Jumping□ Overuse□ Collision with player□
   Kicking ball□ Burns (from grass) □ Other□(please specify) ____________

7. **Did you stop playing soccer as a result of the injury/injuries?** Yes□ No□

8. **If yes, how long have you been unable to participate in soccer for?** ______

9. **How many injury/injuries did you have due to playing soccer last season?**
   ____________ (if none, please proceed to Part C.)

10. **Which part/s of your body was injured? (You may choose more than 1)**
    Head□ Face□ Neck□ Shoulder□ Elbow□ Wrist□ Hand/Finger□ Chest□ Abdomen□ Back□
    Groin□ Thigh□ Knee□ Leg/Calf□
    Ankle□ Foot□ Other□(please specify) _______

11. **When did your injury/injuries occur?** Please specify_______________

12. **Did the injury occur during:** Match play □ Training □ Both □

13. **How would you describe the injury/injuries?(You may choose more than 1)**

Cut □ Graze □ Bruise □ Muscle injury □

Fracture (Broken bone) □ Other □(please specify) _______

14. **How did you hurt yourself? (Please tick more than 1 if applicable)**

Tackle □ Turning□ Landing□ Running□

Heading the ball □ Jumping□ Overuse□ Collision with player□

Kicking ball□ Burns (from grass) □ Other□(please specify)_______

15. **Did you stop playing soccer as a result of the injury/injuries?** Yes□ No□

16. **If yes, how long have you been unable to participate in soccer for?** ______

PART C: EQUIPMENT

1. **What footwear do you wear when playing soccer?**

Takkies/Trainers□ Soccer boots□ Other□(please specify) ___________

2. **Do you wear shin guards during:** Matches□ Training□ Neither□
3. **Do you wear ankle protection during:** Matches□ Training□ Neither□
4. **Do you wear knee protection during:** Matches□ Training□ Neither□

5. **What surface do you play soccer on?**

Grass□ Astroturf□ Ground□ Tar road surface□

6. **Were you wearing protective equipment when your injury/injuries occurred?**

Yes□ No□

PART D: TREATMENT

1. **Did you self-treat your injury/injuries?** Yes□ No□

If yes please specify_________(E.g. Rest, Ice, Compression,Elevation, Stretch)

2. **Did you receive any advice for the injury?** Yes□ No□

If yes, please choose one or more options below:

Rest□ Limit sport activity□ Full sport activity□

3. **Do you have any access to healthcare during training/matches?** Yes□ No□
4. **Which healthcare service is available to you during training/matches?**

Medical/Paramedical□ Chiropractic□ Physiotherapy□ Biokineticist□

Sports Massage Therapy□ Other□(please specify) ___________

5. **What exercises or activities do you perform during training?**

Warming-up□ Stretching□ Jogging□ Match drills□ Cool down□

Other□(please specify)________

6. **Do you have any access to healthcare at school?**

Yes□ No□ Sometimes□

PART E: MEDICAL AND NUTRITIONAL PROFILE

1. **Do you suffer from any medical condition/s?**

   Yes□ No□ (if no, then proceed to question 3)

   If yes, please name the condition/s________________

   (E.g. Anaemia, Diabetes Mellitus, High Blood Pressure, Asthma)

2. **Do you take medication for the condition/s?** Yes□ No□

3. **Do you have any abnormality/abnormalities that you were born with?**

   Yes□ No□ (if no, then proceed to question 5)

   If yes, please specify ______________

4. **What treatment are you having for your condition/s?** ________________

5. **Have you been advised/prescribed any specific diet?** Yes□ No□

   If yes, please specify ________________

6. **Do you drink water or any other form of fluids (such as energy drinks) during soccer training or matches?** Yes□ No□

   If yes, please specify ________________

7. **Do you take any supplements (such as medical, nutritional or vitamin supplements)?** Yes□ No□

Please include anything you want to say in the space below

____

____

____

Thank you for participating in this study.

Appendix H: Learner Information Letter

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
LETTER OF INFORMATION

Dear Learner

Thankyou for your time.

I am a Chiropractic Masters student at the Durban University of Technology (DUT). I am in the process of undertaking a research project and I humbly ask for your help and permission to participate in my study. My study involves adolescent female soccer players.

Permission to do the study has been given by the KwaZulu-Natal Department of Education and the DUT ethics committee.

Title of the Research Study: The relationship between postural stability, sway, balance, and injury in adolescent female soccer players in the eThekwini District of KwaZulu-Natal.

Researcher: JP Koenig, B. Tech Chiropractic

Supervisor: Prof. T. Puckree, PhD PT

Brief Introduction and Purpose of the Study: In order to understand what my study is about, I am trying to see whether there is a link between postural stability – or how stable a person is when they are standing, the balance of the person, and injury. This will involve adolescent female soccer players.

The information that I gather will help us to understand a number of things. Firstly, the effect that injury has on balance and stability; secondly how much of a risk factor poor balance is for injury; and lastly the study will provide greater understanding of the importance of balance training as an addition to normal soccer training in order to prevent future injury.

Outline of the Procedures: In order for you to be considered for the study, you have to meet the inclusion criteria and if you do not meet these criteria you will not be able to take part. If you do not understand these criteria please ask your parent/guardian/teacher. I will explain these criteria as much as I can during our information session.

Inclusion criteria:

- Females between 14-19 years of age.
- All participants had to have played soccer in the previous season.
- Only participants whose parents/guardians (if below 18) had signed the letter of informed consent will be included in the study.
- Only participants, who signed the letter of informed consent (if over 18) and assent with (if below 18) participating will be included in the study.

Exclusion Criteria

- Pregnant learners and those suspecting that they may be pregnant will be excluded from the study because of the ability to obscure or change the measurements related to the study.
- Participants who have any form of systemic, neurological, vestibular, or vascular disease that may affect their balance and stability will be excluded from the study.
- Participants who suffer from vertigo or have benign positional vertigo will be excluded from the study.
- Participants who have recently had surgery will be excluded from the study.
- Participants who have suffered from severe trauma the extent of which will make them unable to participate fully in the study.

According to http://www.rightdiagnosis.com/b/balance/subtypes.htm, types of disorders that may affect balance include peripheral vestibular balance disorder (ear affected), central vestibular balance disorder (brain affected), systemic balance disorder (major body systems affected), vascular balance disorder (blood flow affected), vertigo, and benign positional vertigo.

The procedure of this study will involve two sessions – the first of which will be a short information session in which I will speak to you (soccer playing learners between 14 and 19 years) and hand out information forms, consent forms and assent forms. I will then explain the whole procedure to you, and will underline the importance of consent and assent. There will be a short question/answer session at the end of the session. You will be asked to take the information forms, consent forms and assent forms home for your parents/guardians and yourselves to sign. You will also be told when the next session is and that you will only be allowed to take part in the study if you have consent or permission and have assented to participating. This first session will take approximately 30 minutes of your time. The second session will be arranged with your principal and will be at a time suitable for everyone.

The second session will involve you moving through a number of stations. This session will be at your school if there are facilities available. If not, it will be at the Durban University of Technology and transport will be available for you.

STATION 1: Here, you will be requested to hand in your personal and parental consent forms and assent forms which will be checked. If successful, you will move on to the next station.

STATION 2: Here you will be required to fill in a questionnaire provided by the fellow researcher.

STATION 3: At this station you will be required to take your shoes and socks off and you will first have your height and weight measured to determine your body mass index. You will then be instructed to stand on the Biodex Biosway Balance platform (Biodex Inc.). I will provide further instructions. This will involve you standing on the Biosway unit on a firm and foam surface with your eyes open and closed. Your movement pattern will also be assessed. The Biosway unit is basically a platform that you stand on (like a scale) and is completely safe.

Station 1 and 2 should take a total of 30 minutes for the whole group and Station 3 should take 15 minutes per participant.

Risks or Discomforts to you, the Participant: There are no risks or discomforts to you.

Benefits: Benefits to the researcher:
This study will create a better understanding of the effect injury has on balance, of whether poor balance is a risk factor for injury, and of the importance of balance training in order to prevent future injury on the playing field.

Benefits for you, the participant:
This research will benefit you, the participant directly as information about your balance and stability and its role in your injury or future injury may be seen. This research will also benefit you indirectly as the information gathered will provide understanding in relation to poor balance as a risk factor for soccer injury and the importance of balance training to prevent getting injured in future.

Reason/s why you may be withdrawn from the study: You, the participant may withdraw at any time from the study should you so wish. Reasons for which you may be withdrawn from the study include – you not being able to participate fully in the study, illness, and any other uncontrollable circumstances. There will be no negative consequences for you should you choose to withdraw.

Confidentiality: Your identity will be protected via a coding system, which will be used for writing up my project and publishing. Also, assessment of your balance, stability, height and weight will be performed behind closed doors so it will be completely private and confidential.

Research-related Injury: Although there is an extremely low risk of you getting injured during the research process, if it does happen then your teachers and principal will be told. They will contact your parents/guardians and you will be taken to your doctor or the hospital. Your safety and care is very important.

Persons to Contact in the Event of Any Problems or Queries:
Researcher: JP Koenig (073 191 6896). The Institutional Research Ethics Administrator (031 373 2900). Complaints can be reported to Professor F. Otieno (031 373 2382) or dvctip@dut.ac.za.

Your assistance would be highly appreciated and is very important to this research.
Thanking you sincerely

JP Koenig (073 191 6896)
Researcher

Prof. T. Puckree (031 373 2704)
Research Supervisor

Appendix I: Parent Information letter

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)
LETTER OF INFORMATION

Dear Parent/Guardian

Thankyou for your time.

I am a Chiropractic Masters student at the Durban University of Technology. I am in the process of undertaking a research project and humbly request your assistance/ permission to allow selected learners to participate in my study. My study involves adolescent female soccer players.

Permission to conduct the study has been provided by the KwaZulu-Natal Department of education and the Durban University of Technology research ethics committee.

Title of the Research Study: The relationship between postural stability, sway, balance, and injury in adolescent female soccer players in the eThekwini District of KwaZulu-Natal.

Researcher: JP Koenig, B. Tech Chiropractic

Supervisor: Prof. T. Puckree, PhD PT

Brief Introduction and Purpose of the Study: This study will investigate whether there is a relationship between postural stability or how stable one is when in a standing position, balance and injury in high school female soccer players.

The information gathered will help us to understand a number of things. Firstly, the effect that injury has on balance and stability; secondly to what extent poor balance is a risk factor for injury; and lastly the study will provide greater clarity in terms of the importance of balance training as an addition to a normal soccer training program in order to prevent future injury.

Outline of the Procedures: In order for the learner to be considered for the study, they have to meet the inclusion criteria and if they do not meet these criteria they will not be able to participate.

Inclusion criteria:

- Females between 14-19 years of age.
- All participants had to have played soccer in the previous season.
- Only participants whose parents/guardians (if below 18) had signed the letter of informed consent will be included in the study.
- Only participants, who signed the letter of informed consent (if over 18) and assent with (if below 18) participating will be included in the study.

Exclusion Criteria

- Pregnant learners and those suspecting that they may be pregnant will be excluded from the study because of the ability to obscure or change the measurements related to the study.
- Participants who have any form of systemic, neurological, vestibular, or vascular disease that may affect their balance and stability will be excluded from the study.
- Participants who suffer from vertigo or have benign positional vertigo will be excluded from the study.
- Participants who have recently had surgery will be excluded from the study.
- Participants who have suffered from severe trauma the extent of which will make them unable to participate fully in the study.

According to http://www.rightdiagnosis.com/b/balance/subtypes.htm, types of disorders that may affect balance include peripheral vestibular balance disorder (ear affected), central vestibular balance disorder (brain affected), systemic balance disorder (major body systems affected), vascular balance disorder (blood flow affected), vertigo, and benign positional vertigo.

The procedure of this study will involve two sessions – the first of which will be a short information session in which the researcher will speak to the learners (soccer playing learners between 14 and 19 years) and hand out information forms, consent forms and assent forms. The researcher will explain the whole procedure to the learners, and will underline the importance of consent and assent. There will be a short question/answer session at the end of the session. The learners will be required to take the information, consent forms and assent forms home for their parents/guardians and themselves to sign. The learners will also be told when the next session is and that only those who have consent and assent will be allowed to take part in the study. This first session will take approximately 15 minutes of the learner's time. The second session will be arranged with the principal and will be at a time suitable for everyone.

The second session will involve the learners (participants) moving through a number of stations. This session will be at the school if adequate facilities are available. If not, it will be at the Durban University of Technology and transport will be available for the participants.

STATION 1: Here the participant will be requested to hand in their personal and parental consent forms and assent forms which will be checked. If successful, the participant will move on to the next station.

STATION 2: Here the participant will be required to fill in a questionnaire provided by the fellow researcher.

STATION 3: At this station the participant will be required to take their shoes and socks off and will have their height and weight measured in order to determine their body mass index. The participant will then be instructed to stand on the Biodex Biosway Balance platform (Biodex Inc.). The researcher will instruct the participant as to what to do. This will involve the participant standing on the

Biosway unit on a firm and foam surface with their eyes open and closed. Each participant's movement pattern will also be assessed.

At each of the aforementioned points, the researcher will take a number of readings on the Biosway computer.

Station 1 and 2 should take a total of 30 minutes for the whole group and station 3 should take 15 minutes per participant.

The Biodex Biosway Portable Balance System is a device used to assess balance and is also used as a training device. It provides valid and reliable objective measures of a participant's neuromuscular control and ability to balance on a firm and/or unstable surface (Biosway Portable Balance System Operation Manual, Biodex Medical Systems Inc., Shirley, New York).

Risks or Discomforts to the Participant: There are no risks or discomforts to the participant.

Benefits: Benefits to the researcher:
This study will create a better understanding of the effect injury has on balance, of whether poor balance is a risk factor for injury, and of the importance of balance training in order to prevent future injury on the playing field.

Benefits for the participant:
This research will benefit the participants directly as information regarding their balance and its role in their injury may be identified. This research will also benefit the participants indirectly as the information gathered will provide incite in relation to poor balance as a risk factor for soccer injury and the potential importance of balance training to prevent injury.

Reason/s why the Participant May Be Withdrawn from the Study: The participant may withdraw at any time from the study should they so wish. Reasons for which the participant may be withdrawn from the study include - non-compliance, illness, and any other unforeseen circumstances. There will be no adverse consequences for the participant should they choose to withdraw.

Confidentiality: The identity of the participant will be protected via a coding system, which will be used for writing up the dissertation and publication. Also, assessment of each participant's balance, stability, height and weight will be performed behind closed doors so it will be completely confidential.

Research-related Injury: Although there is an extremely minimal risk of injury occurring during the research process as it is non-invasive, measures will be taken to ensure participant safety and care. The appropriate school authorities will be notified and the school injury protocol will be followed. The participant's parents/guardians and family doctor (or hospital) will be contacted and all will be done to ensure the injured participant is correctly taken care of.

Persons to Contact in the Event of Any Problems or Queries:
Researcher: JP Koenig (073 191 6896). The Institutional Research Ethics Administrator (031 373 2900). Complaints can be reported to Professor F. Otieno (031 373 2382) or dvctip@dut.ac.za.

Your assistance would be highly appreciated and vital to this research.

Thanking you sincerely
JP Koenig (073 191 6896)
Researcher

Prof. T. Puckree (031 373 2704)
Research Supervisor

Appendix J: Participant Information Sheet (N=80)

Participant number	Age	Height	Weight	Body Mass Index	School	Consent/assent signed	Biodex Reference number

Appendix K: Research in Progress Poster

RESEARCH IN PROGRESS

BALANCE ASSESSMENT OF FEMALE HIGH SCHOOL SOCCER PLAYERS

DATE: ……………………

NAME OF SCHOOL: ……………………………..

QUIET…..RESEARCH IN PROGRESS.

Appendix L: Steps in the Research Process

STEP 1

- **HAND IN CONSENT FORM FROM PARENTS/GUARDIAN AND ASSENT FORM IF UNDER 18 YEARS OLD**

- **HAND IN PERSONAL CONSENT FORM AND ASSENT FORM IF OVER 18 YEARS OLD (NOTE: IF YOU DO NOT HAVE THE CORRECT FORM YOU CANNOT PARTICIPATE IN THIS RESEARCH).**

STEP 2

FILL IN QUESTIONNAIRE

(NOTE: REMEMBER TO FILL IN YOUR PARTICIPANT NUMBER AT THE TOP OF THE SHEET – YOU WILL EACH BE GIVEN A NUMBER).