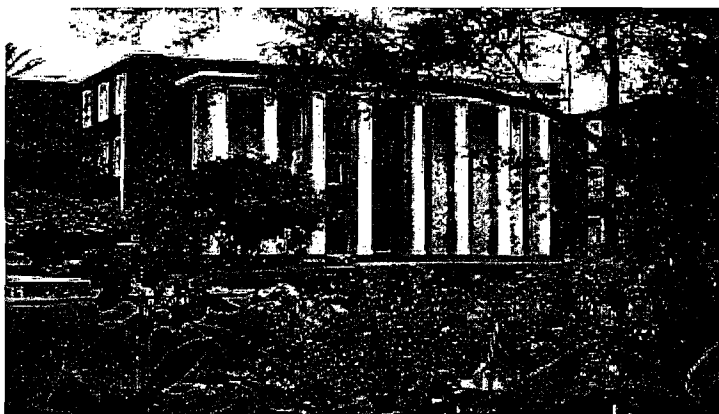


**A prediction model for the prevention of soccer injuries amongst
youth players**

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“The only way to predict the future is to have power to shape the future” Eric Hoffer
(American writer 1902 - 1983)

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SUMMARY

Background: Football (Soccer) is arguably the most popular sport in the international sporting arena. A survey conducted by FIFA (Fédération Internationale de Football Association) (FIFA, 2000) indicated that there are 240 million people who regularly play soccer around the world. Internationally, there are 300 000 clubs with approximately 1.5 million teams. In South Africa, there were 1.8 million registered soccer players in 2002/2003 (Alegi, 2004). Although youth players are predominantly amateurs and have no financial value for their clubs or schools, their continued health and safety are still of vital importance. There are some clubs which contract development players at 19 years of age in preparation for playing in their senior sides and these young players should be well looked after, to ensure a long career playing soccer. Being able to predict injuries and prevent them would be of great value to the soccer playing community.

Aims: The main aim of this research was to create a statistical predictive equation combining biomechanics, balance and proprioception, plyometric strength ratios of ND/Bil (Non dominant leg plyometrics/ Bilateral plyometrics), D/Bil (Dominant leg plyometrics/ Bilateral plyometrics) and ND+D/Bil (Non dominant leg + dominant leg plyometrics/ Bilateral plyometrics) and previous injuries to determine a youth soccer player's risk of the occurrence of lower extremity injuries. In the process of reaching this aim it was necessary to record an epidemiological profile of youth soccer injuries over a two season period. It was also necessary to record a physical profile of, and draw comparisons between, school and club youth soccer players. Following the creation of the prediction model a preventative training programme was created for youth soccer players, addressing physical shortcomings identified with the model.

Design: A prospective cohort study

Subjects: Schoolboy players from two schools in the North West Province, as well as club players from three age groups were used for this study. Players from the U/16 and U/18 teams in the

two schools were tested prior to the 2007 season. Players from the U/17, U/18 and U/19 club development teams were tested prior to the 2008 season. The combined total number of players in the teams amounted to 110 players.

Method: The test battery consisted of a biomechanical evaluation, proprioceptive and plyometric testing and an injury history questionnaire. The Biomechanical evaluation was done according to the protocol compiled by Hattingh (2003). This evaluation was divided into five regions with a dysfunction score being given for each region. A single limb stance test was used to test proprioception. A Sergeant jump test was utilised using the wall mark method to test plyometric jumping height. A previous injury questionnaire was also completed on all players prior to testing. Test subjects from the schools were tested with the test battery prior to commencement of the 2007 season. The testing on the club teams was undertaken prior to the 2008 season. Injuries were recorded on the prescribed injury recording form by qualified Physiotherapists at weekly sports injury clinics at each of the involved schools and clubs. The coaching staff monitored exposure to training activities and match play on the prescribed recording forms. These training and match exposure hours were used, along with the recorded injuries for creating an epidemiological profile. Injuries were expressed as the amount of injuries per 1000 play hours. Logistical regression was done by using the test battery variables as independent variables and the variable injured/not injured as dependent variable (Statsoft, 2003). This analysis created prediction functions, determining which variables predict group membership of injured and non injured players.

Results: There were 110 youth players involved in the research study from seven teams and four different age groups. There were two groups of U/16 players, an U/17 group, three U/18 groups and an U/19 group. The players were involved in a total of 7974 hours of exposure to training and match play during the seasons they were monitored. The average age of the players was 16.6 years. The majority of players were right limb dominant (83.6%) and 65.7% of players

failed a single limb stance test. The mean jump height for both legs combined was 33.77cm, with mean heights of 22.60cm for dominant leg jump and 22.66cm for the non dominant leg.

In the biomechanical evaluation of the lower leg and foot area, the average youth player presented with adaptation of toes, normal or flat medial foot arches, a normal or pronated rear foot in standing and lying and a normal or hypomobile mid-foot joint. Between 42.7% and 51.8% of players also presenting with decreased Achilles tendon suppleness and callusing of the transverse foot arch.

The youth profile for the knee area indicated that the players presented with excessive tightness of the quadriceps muscles, normal patella tilt and squint, normal knee height, a normal Q-angle, a normal VMO:VL ratio and no previous injuries. This profile indicated very little dysfunction amongst youth players for the knee area.

For the hip area, the youth profile was described as follows: There was shortening of hip external rotators, decreased Gluteal muscles length, normal hip internal rotation and no previous history of injury. Between 38.2% and 62.7% of players also exhibit shortened muscle length of the adductor and Iliopsoas muscles and decreased length of the ITB (Iliotibial Band).

In the Lumbo-pelvic area there was an excessive anterior tilt of the pelvis with normal lumbar extension, side flexion, rotation and lumbar sagittal view without presence of scoliosis. Between 58.18% and 65.45% of players presented with an abnormal coronal view and decreased lumbar flexion. Between 41.81% and 44.54% of players also presented with leg length, ASIS, PSIS, Cleft, Rami and sacral rhythm asymmetry. The similarity of the results for these tests in all players contributed to a new variable called 'SIJ dysfunction'. This was compiled from the average of the scores for Leg length, ASIS, PSIS, Cleft, Rami and Sacral rhythm, which was also considered for inclusion in the prediction model.

The neurodynamic results of youth players indicated that approximately between 44.54% and 50.91% of players presented with decreased Straight leg raise and Prone knee bend tests. The total combined dysfunction scores for the left and right sides were 17.091 and 17.909 respectively, indicating that there were higher levels of dysfunction on the right side than the left. This increased unilateral dysfunction could probably be attributed to limb dominance and increased use of the one leg for kicking and passing during the game.

In the epidemiological study on youth players, there was a total of 49 training injuries and 52 match injuries. The total injury rate for youth players was 12.27 injuries/1000 hours, with a total match injury rate of 37.12 injuries/1000 match hours. The combined training injury rate was 7.17 injuries/1000 training hours. 87.13% of injuries were of the lower limb area and the individual areas with the highest percentage of injuries were the Ankle (25.74%), Knee (19.80%), Thigh (15.84%) and Lower leg (14.85%). The totals for youth players indicated that sprains (30.69% of total), strains (27.72% of total) and contusions (27.72% of total) were the most common causative mechanism of injuries. The severity of injuries show 'zero day' (no time off play) injuries to be the most common type (35.64%), followed by 'slight' (1 to 3 days off play) (33.66%) and 'minor' (4 to 7 days off play) (14.85%). School players had higher injury rates than club players but the severity of injuries to club players was higher, with longer absences from play. Non-contact injuries accounted for 52.47% of the total with 46.53% being contact injuries. School players had lower levels of non-contact injuries than club players, which correlated well with lower dysfunction scores recorded for school players during the biomechanical evaluations. This demonstrated that there was a definite relationship between levels of biomechanical dysfunction and the percentage of non-contact injuries in youth players, which formed the premise of the creation of a prediction model for non-contact youth soccer injuries.

The next step in the creation of a prediction model was to identify the variables that discriminated maximally between injured and non-injured players. This was done using stepwise logistic

regression analysis. After the analysis, ten variables with the largest odds ratios were selected for inclusion in the prediction model to predict non-contact injuries in youth soccer players. The prediction model created from the stepwise analysis presented as follows:

$$P(\text{injury}) = \frac{\exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}{1 + \exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}$$

a = Toe dysfunction

b = Previous ankle injury

c = Ankle dysfunction

d = SIJ dysfunction

e = Lumbar Extension

f = Straight Leg Raise

g = Psoas length

h = Patella squint

i = Gluteal muscle length

j = Lumbar dysfunction

P = probability of non contact injury

$\exp(x) = e^x$, with e the constant 2.7183

In the ankle area, the toe positional test, previous ankle injury history and combined ankle dysfunction score were included in the prediction model. In the knee area, the patella squint test was included in the model. In the hip area, the Psoas component of the Thomas test was included, along with the Gluteal muscle length test. In the Lumbo-pelvic area, the SIJ dysfunction (average of Leg length, ASIS, PSIS, Rami, Cleft and Sacral rhythm tests), lumbar extension test and lumbar dysfunction scores were included in the prediction model. In the neurodynamic area, the Straight leg raise test was included in the prediction model. The prediction model therefore contained tests from all five the biomechanical areas of the body. Overall, this model correctly predicted 86.91% of players as either injured or not-injured. The I value (effect size index for improvement over chance) of the prediction model ($I=0.67$), along with the sensitivity (65.52%), specificity (94.87%), overall correct percentage of prediction (86.91%) and Hosmer and Lemeshow interferential goodness-to-fit value ($X^2(8) = 0.7204$), all demonstrated this prediction model to be a valid and accurate prediction tool for non-contact youth soccer injuries.

A second prediction model, for the prediction of hip and groin injuries amongst youth players, was also created. The prediction model created from the stepwise analysis for groin injuries presents as follows:

$$P(\text{Groin injury}) = \frac{\exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}{1 + \exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}$$

d = SIJ dysfunction

k = Previous knee injury

m = Previous hip injury

e = Lumbar extension

f = Straight leg raise

n = Limb dominance

p = ND/Bil plyometric ratio

P = probability of groin injury

$\exp(x) = e^x$, with e the constant 2.7183

The prediction model for hip and groin injuries included the variables of SIJ dysfunction, previous knee injury, previous hip injury, lumbar extension, straight leg raise, limb dominance and the ratio of non-dominant leg to bilateral legs plyometric height. When all the validifying tests were examined, the I-value (0.64868), sensitivity (66.67%), specificity (98.01%), false negatives (1.98%), false positives (33.33%), Hosmer and Lemeshow goodness-to-fit value ($X^2(8) = 0.77$) and the overall percentage of correct prediction (96.26%) all reflected that this model was an accurate prediction tool for hip and groin injuries amongst youth soccer players.

Conclusion: This study showed that it was possible to create a prediction model for non-contact youth soccer injuries based on a pre-season biomechanical, plyometric and proprioceptive evaluation along with a previous injury history questionnaire. This model appears as follows:

$$P(\text{injury}) = \frac{\exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}{1 + \exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}$$

a = Toe dysfunction

b = Previous ankle injury

c = Ankle dysfunction

d = SIJ dysfunction

e = Lumbar Extension

f = Straight Leg Raise
 g = Psoas length
 h = Patella squint
 i = Gluteal muscle length
 j = Lumbar dysfunction
 P = probability of non contact injury
 $\exp(x) = e^x$, with e the constant 2.7183

It was also possible to create a prediction model for non contact hip and groin injuries, which appears as follows:

$$P(\text{Groin injury}) = \frac{\exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}{1 + \exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}$$

d = SIJ dysfunction
 k = Previous knee injury
 m = Previous hip injury
 e = Lumbar extension
 f = Straight leg raise
 n = Limb dominance
 p = ND/Bil plyometric ratio
 P = probability of groin injury
 $\exp(x) = e^x$, with e the constant 2.7183

Using the hip and groin prediction model, combined with the injury prediction model, injuries in youth soccer players can be predicted. The data for each player should first be substituted into the injury prediction model, to determine the chance of getting injured during the season. The data should then be substituted into the hip and groin injury prediction model, determining the chance of hip and groin injuries during the season. The results from the groin injury prediction model could then be used to exclude groin injuries amongst players. A negative result for the hip and groin injury, which showed a false negative percentage of 1.98%, could be used to determine that an injury that was predicted using the overall injury prediction model, would not be a hip and groin injury. A positive result in the groin injury test could, however, not exclude injuries to other body areas that were predicted by the overall injury prediction model, so the groin injury prediction model could only be used to exclude hip and groin injuries.

Keywords: Youth soccer, soccer injuries, soccer injury prevention, soccer injury prediction, youth biomechanical profile, soccer injury epidemiology, proprioception, plyometrics

OPSOMMING

Agtergrond: Sokker is heel moontlik die mees populêre sport in die internasionale sportmilieu. 'n Opname deur FIFA (Fédération Internationale de Football Association) (FIFA, 2000) het aangetoon dat daar 240 miljoen mense is wat gereeld sokker speel rondom die wêreld. Internasionaal is daar meer as 300 000 klubs met ongeveer 1.5 miljoen spanne. In Suid Afrika, was daar 1.8 miljoen geregistreerde sokkerspelers in 2002/2003 (Alegi, 2004). Alhoewel jeugspelers oorwegend amateurs is en geen finansiële waarde vir hulle klubs of skole het nie, is hulle voortgesette gesondheid en veiligheid steeds van kardinale belang. Daar is sommige klubs wat spelers op 19-jarige ouderdom reeds kontrakteer om hulle voor te berei om vir die senior spanne te speel. Die jong spelers moet goed opgepas word om 'n lang sokker loopbaan te verseker. Die moontlikheid om beserings te kan voorspel en te voorkom sal van onskatbare waarde vir die sokkergemeenskap wees.

Doelwitte: Die hoofdoelwit van die navorsingstudie was om 'n statistiese voorspellingsformule wat biomeganika, balans en proprioëpsie, pliometriese verhoudings van ND/Bil (Nie-dominante been plofkrag/ Bilaterale plofkrag), D/Bil (Dominante been plofkrag/ Bilaterale plofkrag) en ND+D/Bil (Nie-dominante been + dominante been plofkrag/ Bilaterale plofkrag) en ook vorige beserings bevat te skep om 'n jeug sokkerspeler se risiko van been beserings te bepaal. In die proses was dit ook nodig om 'n epidemiologiese profiel van jeug sokkerspelers oor 'n periode van twee seisoene te bepaal. Dit was ook nodig om 'n fisiese profile van jeug sokker spelers saam te stel en vergelykings te tref tussen skool- en klubsokkerspelers. Na aanleiding van die voorspellingsmodel is daar ook 'n voorkomende oefenprogram saamgestel wat tekortkominge aanspreek wat deur die voorspellingsmodel geïdentifiseer is.

Ontwerp: 'n Prospektiewe kohortstudie

Ondersoekpopulasie: Skoolspelers van twee skole in die Noordwes Provinsie, sowel as klubspelers van drie ouderdomsgroepe het deel gevorm van die studie. Spelers van die O/16 en

O/18-spanne van die twee skole is getoets voor die aanvang van die 2007-seisoen. Spelers van die O/17, O/18 en O/19-klub jeugspanne is getoets voor die aanvang van die 2008-seisoen. Die totale aantal deelnemers van al die spanne saam was 110 spelers.

Metode: Die toetsbattery het bestaan uit 'n biomeganiese evaluasie, proprioepsie en pliometriese toetsing en 'n beseringsgeskiedenis vraelys. Die biomeganiese evaluasie is gedoen volgens die protokol wat deur Hattingh (2003) saamgestel is. Hierdie evaluasie word opgedeel in vyf streke met 'n disfunksietelling wat vir elke streek gegee word. 'n Enkel-been-staan-toets is gebruik vir die proprioepsietoets. 'n Sergeant plofkragtoets met die muur-merk metode is gebruik vir die pliometriese toetsing. 'n Beseringsgeskiedenis vraelys is ook voltooi vir alle spelers alvorens daar met toetsing begin is. Proefpersone van die skole is met die toetsbattery ge-evalueer voor die aanvang van die 2007-seisoen. Die toetsing op die klubspelers is gedoen voor die aanvang van die 2008-seisoen. Beserings is aangeteken op die gespesifiseerde beseringsvorm deur 'n gekwalifiseerde Fisioterapeut by weeklikse beseringsklinieke by die skole en die klub. Die afrigtingspersoneel het blootstelling aan oefening en wedstryde aangeteken. Hierdie oefen- en wedstryd-blootstellingsure is saam met die aangetekende beserings gebruik om die epidemiologiese profiel te skep. Beserings is gerapporteer as beserings per 1000 speelure. Logistiese regressie is gedoen deur die toetsbattery veranderlikes te gebruik as onafhanklike veranderlikes en die veranderlike beseer/onbeseer as afhanklike veranderlike (Statsoft, 2003). Hierdie analise het voorspellingsfunksies geskep, wat bepaal het watter veranderlikes groeplidmaatskap van “beseerde” of “onbeseerde” spelers bepaal.

Resultate: Daar was 110 jeugspelers van vier verskillende ouderdomsgroepe en sewe spanne betrokke by die navorsing. Daar was twee groepe O/16-spelers, 'n O/17-groep, drie O/18-groepe en 'n O/19-groep. Die spelers was betrokke by 'n som van 7974 ure van blootstelling aan oefeninge en wedstryde gedurende die seisoene wat hulle gemonitor was. Die gemiddelde ouderdom van spelers was 16.6 jaar. Die meerderheid van spelers was regs dominant (83.6%) en 65.7% van spelers het die

enkel-been-staan toets nie geslaag nie. Die gemiddelde springhoogte vir albei bene saam was 33.77cm, met 'n gemiddelde hoogte van 22.60cm vir die dominante been sprong en 22.66cm vir die nie-dominante been.

In die biomeganiese evaluasie van die onderbeen- en voetarea het die gemiddelde jeugspeler vertoon met aanpassing van die tone, normale of plat mediale voetboë, 'n normale of gepronseerde agtervoet in staan en lê, 'n normale of hipomobiele midvoet-gewrig met tussen 42.7% en 51.8% van die spelers wat ook vertoon met verminderde Achilles tendon-soepelheid en kallusformasie van die transvers-voetboog.

Die knieprofiel vir die knie-area, het aangetoon dat spelers vertoon met oormatige styfheid van die kwadriseps-spier, normale patella-tilting en "squint", normale kniehoogte, normale Q-hoek, 'n normale VMO:VL verhouding en geen vorige beserings. Hierdie profiel dui op baie min disfunksie onder jeugspelers vir die knie-area.

Vir die heup-area, het die jeugprofiel as volg gelyk: Daar was verkorting van die heup laterale roteerders, verminderde gluteale spierlengte, normale heup mediale rotasie en geen geskiedenis van vorige beserings nie. Tussen 38.2% and 62.7% van die spelers het ook gepresenteer met verkorte spierlengtes van die adduktore en iliopsoas spiere en verminderde lengte van die Iliotibiale Band.

In die lumbo-pelviese area was daar oormatige anterior tilting van die pelvis, met normale lumbale ekstensie, syfleksie, rotasie en lumbale saggitale beeld sonder die voorkoms van skoliose. Tussen 58.18% en 65.45% van die spelers het vertoon met 'n abnormale koronale beeld en verminderde lumbale fleksie. Tussen 41.81% en 44.54% van die spelers het gepresenteer met beenlengte, ASIS, PSIS, kleft, rami en sakrale ritme asimmetrie. Die eenvormigheid van die resultate vir hierdie toetse vir al die spelers het bygedra tot die skepping van 'n nuwe veranderlike, getitel "SIG (Sakro-Iliale

Gewrig) disfunksie” wat gevorm is uit die gemiddeld van die tellings vir beenlengte, ASIS, PSIS, Kleft, Rami en sakrale ritme. Hierdie veranderlike is ook oorweeg vir insluiting in die voorspellingsmodel.

Die neurodinamiese resultate van jeugspelers het aangedui dat tussen 44.54% en 50.91% van die spelers vertoon met verminderde reguit-been-optel toetse en maaglê-knie-buig toetse. Die gekombineerde disfunksietelling vir die linker en regter kante was 17.091 en 17.909 repektiewelik. Dit dui aan dat daar hoër vlakke van disfunksie was aan die regterkant as aan die linkerkant. Die verhoogde unilaterale disfunksie kan moontlik toegeskryf word aan beendominansie en verhoogde gebruik van die een been vir skop en aangeewerk gedurende spel.

In die epidemiologiese studie van die jeugspelers, was daar ‘n totaal van 49 oefenbeserings en 52 wedstrydbeserings. Die totale beseringstempo vir jeugspelers was 12.27 beserings/1000 ure, met ‘n totale wedstryd beseringstempo van 37.12 beserings/1000 wedstryd-ure. Die gekombineerde oefenbeseringstempo was 7.17 beserings/1000 oefen-ure. 87.13% van beserings was van die been-area en die individuele areas met die hoogste persentasie van beserings was die enkel (25.74%), knie (19.80%), dy-area (15.84%) en onderbeen (14.85%). Die totaal vir jeugspelers het aangedui dat ligamentbeserings (30.69% van die totaal), spierbeserings (27.72% van die totaal) en kontusies (27.72% van die totaal) die mees algemene tipe beserings was. Die erns van beserings het aangedui dat “nul dag” beserings die mees algemene was (35.64%), gevolg deur “slight” (1 tot 3 dae afwesighedi van spel) (33.66%) en “minor” (4 tot 7 dae afwesigheid van spel) (14.85%). Skoolspelers het hoër beseringstempo’s gehad as klubspelers, maar die erns van beserings van klubspelers was hoër met langer afwesighede van spel. Nie-kontak beserings het 52.47% van beserings uitgemaak met 46.53% van beserings as kontakbeserings. Skoolspelers het laer vlakke van nie-kontak beserings gehad as klubspelers, wat goed korreleer met die laer disfunksietellings wat opgeteken is vir skoolspelers tydens die biomeganiese evaluasie. Dit wys dat daar ‘n definitiewe verhouding bestaan tussen vlakke van biomeganiese disfunksie en die persentasie nie-kontak

beserings in jeugspelers, wat die basis vorm vir die skep van 'n voorspellingsmodel vir nie-kontak jeug sokkerbeserings.

Die volgende stap in die skepping van die voorspellingsmodel was om te identifiseer watter veranderlikes die beste diskrimineer tussen beseerde- en onbeseerde spelers. Dit was gedoen met stapsgewyse logistiese regressie analise. Na die analise, was tien veranderlikes met die grootste kans verhoudings geselekteer vir insluiting in die voorspellingsmodel vir voorspelling van nie-kontak beserings in jeugspelers. Die voorspellingsmodel wat met die stapsgewyse analiese geskep is lyk as volg:

$$P(\text{besering}) = \frac{\exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}{1 + \exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}$$

a = Toonposisie

b = Vorige enkelbeserings

c = Enkel disfunksie

d = SIG disfunksie

e = Lumbale ekstensie

f = Reguit-been-optel

g = Psoas lengte

h = Patella "squint"

i = Gluteale spierlengte

j = Lumbale disfunksie

P = kans op nie kontak besering

$\exp(x) = e^x$, met e die konstante 2.7183

In die enkel-area, was die toon posisionele toets, vorige enkelbeserings geskiedenis en die gekombineerde enkel-disfunksie telling ingesluit in die model. In die knie-area is die patella "squint" toets ingesluit in die model. In die heup-area, was die Psoas Komponent van die Thomas-toets ingesluit, tesame met die gluteale spierlengtetoets. In die lumbo-pelviëse area was die SIG-disfunksie (gemiddeld van beenlengte, ASIS, PSIS, Rami, kleft en sakrale ritme-toetse), lumbale ekstensie-toets en lumbale disfunksietelling ingesluit in die voorspellingsmodel. In die neurodinamiese area was die reguit-been-optel toets ingesluit. Die voorspellingsmodel bevat dus toetse van al vyf die biomeganiese toetsareas. In totaal, het die model 86.91% van spelers korrek

geklassifiseer as beseer of onbeseer. Die I-waarde (effek grootte-indeks vir verbetering oor kans) van die voorspellingsmodel ($I=0.67$), saam met die sensitiwiteit (65.52%), spesifisiteit (94.87%), die totale korrekte persentasie van voorspelling (86.91%) en die Hosmer en Lemeshow interferensiële goedheid-van-passing ($X^2(8) = 0.7204$), wys alles dat die voorspellingsmodel 'n akkurate voorspellingsmodel vir nie-kontak jeug sokkerbeserings is.

'n Tweede voorspellingsmodel vir die voorspelling van heupbeserings onder jeugspelers is ook geskep. Die voorspellingsmodel geskep deur gebruik te maak van stapsgewyse analise lyk as volg:

$$P(\text{Heupbesering}) = \frac{\exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}{1 + \exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}$$

d = SIG disfunksie

k = Vorige kniebesering

m = Vorige heupbesering

e = Lumbale ekstensie

f = Reguit-been-optel

n = Dominansie

p = ND/Bil pliometriese verhouding

P = kans op heupbesering

$\exp(x) = e^x$, met e die konstante 2.7183

Die voorspellingsmodel van heupbeserings sluit in SIG-disfunksie, vorige kniebesering, vorige heupbesering, lumbale ekstensie, reguit-been-optel toets, dominansie en die verhouding van nie-dominante been plofkrag tot bilaterale been plofkrag. Met ondersoek van al die validasie-toetse, was die I-waarde (0.64868), sensitiwiteit (66.67%), spesifisiteit (98.01%), vals negatiewe (1.98%), vals positiewe (33.33%), Hosmer en Lemeshow interferensiële goedheid-van-passing ($X^2(8) = 0.7677$) en die totale persentasie van korrekte voorspelling (96.26%) alles aanduidend dat die model 'n akkurate voorspellings-instrument is vir heupbeserings in jeug sokkerbeserings.

Gevolgtrekkings: Hierdie studie het bewys dat dit moontlik was om 'n voorspellingsmodel vir nie-kontak jeug sokkerbeserings te skep, gebaseer op 'n voorseisoen biomeganiese-, pliometriese- en proprioseptiewe evaluasie, tesame met 'n vraelys van vorige beseringsgeskiedenis. Die model lyk as volg:

$$P(\text{besering}) = \frac{\exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}{1 + \exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}$$

a = Toonposisie

b = Vorige enkelbeserings

c = Enkel disfunksie

d = SIG disfunksie

e = Lumbale ekstensie

f = Reguit-been-optel

g = Psoas lengte

h = Patella "squint"

i = Gluteale spierlengte

j = Lumbale disfunksie

P = kans op nie-kontak besering

$\exp(x) = e^x$, met e die konstante 2.7183

Dit was ook moontlik om 'n voorspellingsmodel te skep vir nie-kontak heupbeserings, wat as volg

lyk:

$$P(\text{Heupbesering}) = \frac{\exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}{1 + \exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}$$

d = SIG disfunksie

k = Vorige knie besering

m = Vorige heup besering

e = Lumbale ekstensie

f = Reguit-been-optel

n = Dominansie

p = ND/Bil pliometriese verhouding

P = kans op nie heupbesering

$\exp(x) = e^x$, met e die konstante 2.7183

Deur gebruik te maak van die heup-beseringsmodel, gekombineer met die beserings voorspellingsmodel, kan beserings in jeug sokkerspelers voorspel word. Die data vir elke speler sal eers in die beserings-voorspellingsmodel ingevoeg word om die kans vir besering te voorspel. Die data word dan in die heup-beseringsvoorspellingsmodel ingevoeg om die kans vir heupbeserings te bepaal. Die resultate van die heup-beseringvoorspellingsmodel kan dan gebruik word om die voorkoms van 'n heupbesering uit te skakel. 'n Negatiewe resultaat vir die heupbeseringsmodel, wat 'n vals

negatiewe persentasie van slegs 1.98% het, kan gebruik word om te bepaal dat 'n besering wat voorspel is met die algemene beseringsvoorspellingsmodel, nie 'n heup besering sal wees nie. 'n Positiewe resultaat in die heupvoorspellingsmodel, sluit egter nie die moontlikheid van beserings aan ander liggaamsareas uit wat voorspel is deur die algemene beseringsmodel nie. Die heup-beseringsvoorspellingmodel kan dus slegs gebruik word om die moontlikheid van heupbeserings uit te skakel.

Sleutelwoorde: Jeugsokker, sokkerbeserings, sokkerbeseringsvoorkoming, sokkerbeseringsvoorspelling, jeug biomeganiese profiel, sokkerbeseringsepidemiologie, proprioepsie, pliometrie

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LIST OF ABBREVIATIONS

ASIS	Pelvic girdle Anterior Superior Iliac Spina
BC	Before Christ
CAF	Confederation of African Football
CEO	Chief Executive Officer
cm	Centimeters
D/Bil	Dominant leg plyometric height/ Bilateral plyometric height
EMG	Electromyograph
FA	Football Association
FASA	Whites-only South African Football Association
FIFA	Fédération Internationale de Football Association
FNB	First National Bank
I	Effect size index for improvement over chance
ITB	Iliotibial Band
L/Bil	Left leg plyometric height/ Bilateral plyometric height
L+R/Bil	Left leg + right leg plyometric height/ Bilateral plyometric height
m	Meters
Milner	Milner High School, Klerksdorp
ND/Bil	Non dominant leg plyometric height/ Bilateral plyometric height
ND+D/Bil	Non dominant leg + dominant leg plyometric height/ Bilateral plyometric height
O ₂	Oxygen
PKB	Prone Knee Bend
PSIS	Pelvic girdle Posterior Superior Iliac Spina
Q-Angle	Quadriceps muscle pull angle
R/Bil	Right leg plyometric height/ Bilateral plyometric height
ROM	Range of Motion
SAAFA	South African African Football Association
SABFA	South African Bantu Football Association
SACFA	South African Coloured Football Association
SAFA	South African Football Association
SAIFA	South African Indian Football Association
SIJ	Sacro-iliac joint
SLR	Straight leg raise
St Conrad's	St Conrad's College, Klerksdorp

TA	Achilles Tendon
The FA	English Football Association
U/12	Players 12 years and younger
U/13	Players 13 years and younger
U/14	Players 14 years and younger
U/15	Players 15 years and younger
U/16	Players 16 years and younger
U/17	Players 17 years and younger
U/18	Players 18 years and younger
U/19	Players 19 years and younger
U/21	Players 21 years and younger
UEFA	Union of European Football Associations
UK	United Kingdom
USA	United States of America
VL	Vastis Lateralis muscle
VL:VMO	Vastis Lateralis muscle to Vastus Medialis Oblique muscle ratio
VMO	Vastus Medialis Oblique muscle
VMO:VL	Vastus Medialis Oblique muscle to Vastis Lateralis muscle ratio
$X^2(8)$	Hosmer and Lemeshow interferential goodness-to-fit value

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CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

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CHAPTER 1

INTRODUCTION AND PROBLEM STATEMENT

1.1 INTRODUCTION

Soccer is arguably the most popular sport in the international sporting arena. A survey conducted by FIFA (Fédération Internationale de Football Association) (FIFA, 2000) indicated that there are 240 million people that regularly play soccer around the world. Internationally, there are 300 000 clubs with approximately 1.5 million teams. In South Africa, there were 1.8 million registered soccer players in 2002/2003 (Alegi, 2004). Soccer also has huge financial revenues, and corporate sponsorships in South Africa in 2003 reached R 640 million (Alegi, 2004). In England, the Premier football league created revenue to the amount of £1.33 billion in the 2003/2004 season (Tunaru, Clark and Viney, 2005). Injuries to players could have serious financial implications for the clubs involved and for the players themselves. Tunaru *et al.* (2005) also reflected that a strong correlation exists between a club's expenditure on player salaries and its league performance, suggesting that players are "high value assets". Although youth players are predominantly amateurs and have no financial value for their clubs or schools, their continued health and safety are still of vital importance. There are some clubs which contract players at 19 years of age in preparation for playing in their senior sides and these young players should be well looked after, to ensure a long career playing soccer.

In the United States, 1.6 million youth soccer injuries presented to a 100 selected USA emergency departments between 1990 and 2003. As participation in soccer

increases, so does the number of people at risk for injuries (Leininger, Knox & Comstock, 2007). With the number of youth players increasing all over the world, including South Africa, it is important to develop strategies to reduce the number of injuries amongst these youth players.

Price, Hawkins, Hulse and Hodson (2004) are of the opinion that, in order to ensure the health and safety of youth soccer players, efforts must be made to prevent and control injuries. There is a need to identify player groups most at risk of injury and to determine the primary dependent and independent variables that will affect the injury rate of the players.

In the face of the 2010 Soccer World Cup, it is vitally important that South Africa, as the host nation, field the strongest possible team without injuries to vital players. These injuries can be carried from youth level, and preventing them at an early developmental stage could only have positive influences on South African soccer. It is thus of utmost importance that strategies be created to firstly identify anatomical sites that are at risk of being injured in youth players and secondly to identify the variables that influence the occurrence of injuries to these areas. Thirdly: these variables need to be addressed to prevent these injuries from occurring in the first place.

Deehan, Bell and McCaskie (2007) conducted research on all the youth players at the Newcastle United Football academy over a five year period. 210 players between the ages of nine and 18 years old were monitored. As with senior players, the largest percentage of injuries was of the lower limb (79% of the total). Non-contact injuries accounted for 69% of injuries. A total of 685 injuries were monitored during the five

year period of the study. Of these, 6.5% of injuries were of the groin and 79% of the lower limb. A combination of these two areas lead to a total percentage of 85.5% of all injuries being to the lower limb, which is similar to the findings of Price *et al.* (2004). Incidence of injuries in these youth players was 0.6 injuries per player per season.

Junge, Cheung, Edwards and Dvorak (2004) recorded injuries in youth soccer players in 12 school teams ranging in age from 14- to 18 years during one season. This study included 145 players. A total of 261 injuries were noted during the season, resulting in an average of 1.8 injuries per player per season. 14.9% of the injuries were classified as overuse injuries. In these players, 77% of the injuries were of the lower limb. The hip and groin area accounted for 9.3% of injuries, the thigh 17.0%, the knee 15%, the lower leg 16.1%, the ankle 17.2% and the foot 5.8%. Training injuries occurred at a rate of 15.4 injuries/1000 training hours and match injuries occurred at a rate of 47.5 injuries/1000 match hours.

It can be seen from studies in youth players that between 77% and 90% of all injuries were of the lower limb. The injury rate ranges between 0.4 and 1.8 per player, per season for studies conducted on these youth players. Between 14.9% and 69% of injuries were recorded as non-contact or overuse injuries. Deehan *et al.* (2007) stress that the prevention of injury is crucial to minimising longer-term degenerative joint disease and persistent dysfunction in youth players. Any interventions should therefore focus on reducing the injuries to the lower limb area and also focus on reducing non-contact or overuse injuries, as these might be preventable.

Soccer players are known to suffer relatively high rates of injury compared with participants in other sports and occupations. It is therefore important for managers of football club teams to reduce this level of risk and, where possible, to ensure the health and safety of players (Hawkins & Fuller, 1999). This also applies to players at youth levels. According to Drawer and Fuller (2002) the risk of acute injury in football is a thousand times greater than that of perceived high risk industries in the UK (United Kingdom). It was also found that although injury treatment and rehabilitation services were adequate, there is a lack of resources for injury prevention. Both studies by Hawkins, Hulse, Wilkinson, Hodson, and Gibson (2001) as well as Price *et al.* (2004) are of the opinion that football players are exposed to a high risk of injury and there is a need to investigate strategies to reduce this risk.

Various studies have been done to investigate the risk of injuries in both soccer players specifically and other athletes. Agre and Baxter (1987) were of the opinion that musculoskeletal deficiencies in collegiate soccer players predisposed them to injuries while Ribiero, Akashi, Sacco and Pedrinelli (2003) found that a definite relationship existed between negative postural changes and increased incidence of lesions. This was ascribed to postural change causing added biomechanical overload to bone-muscle-joint structures, making the involved site more prone to injury. This study was conducted on 50 junior indoor football players between the ages of 9 and 16 years. In the South Africa milieu, Hattingh (2003) implemented a biomechanical evaluation on junior club rugby players that could be used to predict future injuries on the basis of biomechanical abnormalities. These abnormalities have been shown to predispose players to intrinsic injuries. Erasmus (2006) implemented a biomechanical corrective training programme based on this research by Hattingh (2003) amongst

schoolboy rugby players, which showed a decrease in intrinsic injuries in the players. This biomechanical evaluation model could prove the same success with youth soccer players in South Africa.

Serfontein (2006) conducted a study on 240 schoolboy rugby players to determine the influence of proprioception, balance and plyometric strength on lower leg injuries. This study showed that poor L/Bil (Left leg plyometric height/ Bilateral plyometric height), R/Bil (Right leg plyometric height/ Bilateral plyometric height) and L+R/Bil (left and right leg combined plyometric height/ Bilateral plyometric height) ratios had a notable influence on the occurrence of lower leg injuries and that dominance should also be considered in this equation.

Trojian and McKeag (2006) conducted research on 230 male and female athletes in American football, soccer and volleyball from three colleges and a high school. A pre-season single limb stance balance test was administered to all athletes and ankle injuries were monitored during the season. A positive association was found between a positive single limb stance test and an increased risk of ankle sprain. It was thus stated that a single limb balance test could be used to predict those at greatest risk for ankle sprains.

From the literature it can be seen that there are various studies investigating and proving the influence of biomechanics, proprioception and balance on the occurrence of soccer and other sports injuries. There is however, very little literature where these factors are combined and used in a predictive manner on injury occurrence. There is

also no literature on current predictive models for the prevention of soccer injuries in youth soccer players.

1.2 OBJECTIVES

As determined in the literature review, certain problems in youth soccer could be identified. To try and resolve these problems, this study has the following objectives:

1. Creating a physical profile and comparison of school and club youth soccer players.
2. Recording an epidemiological profile of youth soccer injuries over a two season period.
3. To create a statistical predictive equation combining biomechanics, balance and proprioception, plyometric strength ratios of ND/Bil (Non dominant leg plyometrics/ Bilateral plyometrics), D/Bil (Dominant leg plyometrics/ Bilateral plyometrics) and ND+D/Bil (Non dominant leg + dominant leg plyometrics/ Bilateral plyometrics) and previous injuries to determine a youth soccer player's risk of the occurrence of lower extremity injuries.
4. The creation of a preventative training programme for youth soccer players, addressing physical shortcomings identified with the prediction model.

1.3 METHOD

1.3.1 Literature review

To find literature relevant to the subject, searches were conducted using the following media as well as sports and sport medical journals:

- Internet
- EbscoHost (Academic Search Elite)

- Eric (Psychological database)
- South African Journals
- Medline
- Pubmed
- Science Direct
- Sportdiscus

A manual search of the University of North West library computer catalogue was done to find relevant books on the subject.

1.3.2 Empirical investigation

1.3.2.1 Research design

A prospective cohort study will be used, which entails that a group of people is chosen who do not have the outcome of interest (in this study, lower limb injuries). The investigator then measures a variety of variables that might be relevant to the development of the condition (Biomechanics, plyometric strength, balance and proprioception). Over a period of time the people in the sample are observed to assess whether they develop the outcome of interest (Mann, 2003). This design is generally categorised under descriptive research.

The study is further classified as quantitative research, where a large random group of people is used for research, objective instrumentation is used, the design is determined in advance and statistical methods are used for data analysis. This type of research focuses on the analysis of components and phenomenon (Thomas & Nelson, 2001).

1.3.2.2 Choice of subjects

Schoolboy players from two schools in the North West Province, as well as club players from Platinum Stars Youth Football Academy will be used for this study. The schools that were identified for this research were Milner High School and Saint Conrad's College in Klerksdorp. These schools play in the same league and are of similar strength. Players from the U/16 and U/18 teams in these schools will be tested prior to the 2007 season. Players from the U/17, U/18 and U/19 teams of Platinum Stars will be tested prior to the 2008 season. The combined total number of players in the teams will amount to 110 players. These players will then be utilised for the creation of the prediction model.

1.3.2.3 Procedures and methods of data collection

Prior to testing and participation in this study, parents or legal guardians of all players will sign an informed consent form. Consent forms will also be signed by the various principals of the schools and the CEO of Platinum Stars Football Club. Test subjects from the schools will be tested with the test battery prior to commencement of the 2007 season. The examiner will also complete a previous injury questionnaire for each participant, reflecting any injuries during the past two seasons and rehabilitation thereof. During the 2007 season, all injuries will be recorded by a qualified Physiotherapist at weekly sports injury clinics. Exposure to training sessions and matches will also be recorded by the coaching staff of each respective team, who were instructed on the correct collection procedure of the data.

The testing on the teams from Platinum Stars will be undertaken prior to the 2008 season and the same injury and exposure monitoring will occur during the season. At

the end of the season, statistical data processing will be done using the injury data and results of the test battery recording sessions. Using the statistical method of logistical regression (Statsoft, 2003), classification functions will be created, by means of which future risk of non contact injuries could be determined. The created model will be tested for validity with a number of tests, which are described in paragraph 1.3.2.3.3. The data from all players will also be substituted into the classification function, to determine whether they are correctly classified as “injured” or “not injured”.

1.3.2.3.1 Test Battery

1.3.2.3.1.1 Biomechanical Evaluation

A Biomechanical evaluation will be done according to the protocol compiled by Hattingh (2003). This evaluation will be adapted by dividing the individual tests into five regions with a dysfunction score being given for each region. The first region is the foot and lower leg. Tests for this area include: Achilles tendon suppleness test, longitudinal foot arch status test, forefoot positional test, rear foot standing test, rear foot lying test, transverse arch comparison test, foot mobility test and toe positional test. Previous injuries to the area are also taken into consideration. The foot and lower leg area has a dysfunction score calculated out of ten.

The second region is the knee region. Test for this region include: modified Thomas test (Quads component), Quadriceps angle test, patella tilt test, patella squint test, knee height and VMO:VL comparison test. The dysfunction score for the knee region is thus calculated out of eight, with previous injury also taken into consideration.

The third region is the hip area. Tests for this area include: modified Thomas test (ITB and Hip flexor components), Gluteus maximus mobility test, Adductor mobility test, External hip rotation mobility test, Internal hip rotation mobility test and previous injury occurrence. The dysfunction score for hip area is calculated out of 13.

The fourth region is the lumbo-pelvic area. Tests for this area include: Pelvic girdle leg length discrepancy test, Pelvic girdle Anterior Superior Iliac Spina (ASIS) comparison test, Pelvic girdle Posterior Superior Iliac Spina (PSIS) comparison test, Pelvic rami positional test, Sacroiliac crest test, Bilateral pelvic positional test, Thoraco-lumbar fascia test, Sacral rhythm test, Functional spinal extension mobility test, Functional spinal flexion mobility test, Spinal rotational mobility test, Spinal side-flexion mobility test, Coronal axis lumbar area and Sagittal axis lumbar area. The dysfunction level for this area is calculated out of 21.

The last area of inclusion is neurodynamics. Tests integrated in this area include: Straight leg raise neurodynamic test, Prone knee bend neurodynamic test and a slump neurodynamic test. Neural dysfunction is calculated out of six. The total biomechanical dysfunction score for each player is therefore calculated out of 58. This model will help determine whether global dysfunction in certain areas contribute to injuries, or whether only specific components in each area are to blame for injury occurrence.

1.3.2.3.1.2 Balance and proprioception test

A single limb stance test will be used to evaluate balance and proprioception. This test was described by Trojian and McKeag (2006). Subject is asked to stand on a single

limb with eyes closed for 10 seconds. Any movement of arms, the other leg or the supporting leg is defined as a positive test and will indicate decreases in proprioception and balance. This test is a simple pass/fail test, which aids in ease of statistical processing. It is also an easy test to administer and does not require any equipment or specialised training. This test has been proven to be a good predictor of ankle injuries on its own, without the need for further costly and complicated balance tests to be administered (McGuine Greene, Best and Levenson, 2000; Cimbiz & Bayazit, 2004).

1.3.2.3.1.3 Plyometric testing

Plyometric testing will be conducted using a vertical jump test. This test measures the distance a player can leap straight into the air, by marking a wall with chalk and measuring the distance between his outstretched hand and the mark on the wall (Kirby, 1991). This will be conducted with both legs together as well as with each leg separately and will be recorded as the height jumped in centimetres. The ratios of ND/Bil, D/Bil, ND+D/Bil will also be calculated.

The test battery requires a minimum of equipment and is suited for the South African youth club setup with limited resources and funding.

1.3.2.3.2 Injury and exposure recording

Injuries will be monitored during the season and recorded on the prescribed injury recording form by a qualified physiotherapist at weekly sports injury clinics at each of the involved schools and clubs. The coaching staff will monitor exposure to training activities and match play following proper instruction on the methods of data

collection. These training and match hours will be used, along with the recorded injuries for creating an epidemiological profile. Injuries will be expressed as the amount of injuries per 1000 play hours.

1.3.2.3.3 Statistical data processing

Logistical regression will be done by using the test battery variables as dependent variables and the recorded injuries for grouping players into two groups (STATSOFT, Inc., 2003). This analysis creates prediction functions to determine which variables predict membership between two or more naturally occurring groups. In this study, these groups are players with injuries and players without injuries. The test battery will be used as the determining variables. These variables will be used to predict the inclusion of a player in the injured group. A linear equation of the type $GROUP = a + b_1 * x_1 + b_2 * x_2 + \dots + b_m * x_m$ fits this model. In this equation a is a constant and b_1 through b_m are regression coefficients. Those variables with the largest regression coefficients are the ones that contribute most to the prediction of group membership (STATSOFT, Inc., 2004). The Hosmer and Lemeshow inferential goodness-to-fit test (Hosmer and Lemeshow, 2000) will be used on the model to evaluate validity. A cross-validation method will also be used to re-allocate the test results for all the players in the “injured” and “non-injured” groups by means of the model, to determine the observed and predicted frequencies for injury amongst the youth soccer players. Using this classification table documenting the validity of the predicted probabilities, the sensitivity and specificity of the prediction model can be evaluated. The overall correct percentage of prediction will also be determined. Statistica Statistical Software (STATSOFT, Inc., 2004) from the North West University will be used for all the statistical analyses of the data.

There will also be a comparison between the different age groups and between school and club players. The following formula by Cohen (1988) will be used to determine effect sizes of the difference between the means of two groups being compared:

$$d = \frac{|\bar{x}_1 - \bar{x}_2|}{s}$$

$\bar{x}_1$ is the mean of group one and $\bar{x}_2$ is the mean of group two. $s = \frac{1}{2} (S1+S2)$, where S1 and S2 are the standard deviation of the two groups. Cohen gives the following guidelines for the interpretation of the effect size:

$d = 0.2$ (Small effect)

$d = 0.5$ (Medium effect)

$d = 0.8$ (Large effect).

Effect sizes measure practical significance and data with a large effect size is considered to have a large effect on practical significance. As these d-values are only intended as guidelines, the decision was made that a d-value of 0.75 will be considered to have a large effect for the purposes of this study. Injuries will also be expressed as injuries/1000 playing hours for the purpose of the comparisons with other epidemiological research.

1.4 SUMMARY

This chapter gives a short introduction and overview of the research into the creation of a soccer injury prediction model for youth soccer. An overview of the research design, literature study methods and statistical analysis method is also included. The next chapter evaluates existing literature with regards to soccer epidemiology. It also examines the origins of soccer and its history in South Africa.

CHAPTER 2

LITERATURE REVIEW: SOCCER EPIDEMIOLOGY

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2.5 SUMMARY

CHAPTER 2

LITERATURE REVIEW: SOCCER EPIDEMIOLOGY

2.1 INTRODUCTION

This chapter will examine the existing literature regarding soccer that has reference on this research study. An introduction to the sport will be made, shortly explaining the game and its rules as well as the roles of players. A brief history on the origins of soccer will also be given. Existing data on injuries in the sport will also be examined and discussed, analysing the professional game, amateur soccer, female soccer as well as youth soccer. The nature of these injuries will be examined to establish existing injury patterns, which will help with the formulation of goals towards the prevention of these injuries amongst youth players.

2.2 INTRODUCTION TO THE GAME OF SOCCER

Soccer is a game played by two teams on a rectangular field. Players attempt to knock a ball through the opponents' goal post using any part of the body except the arms below the elbow and the hands. Generally, players use their feet and heads as they kick, dribble, and pass the ball toward the goal. One player on each team guards the goal and is called the 'goalkeeper'. This player is the only player allowed to touch the ball with the hands while it is in play (Encarta, 2007).

Soccer is a free-flowing game that requires little equipment and has relatively few rules. All that is needed to play is an area of open space and a ball. This is probably one of the reasons for the sport's immense popularity. Much of the world's soccer is

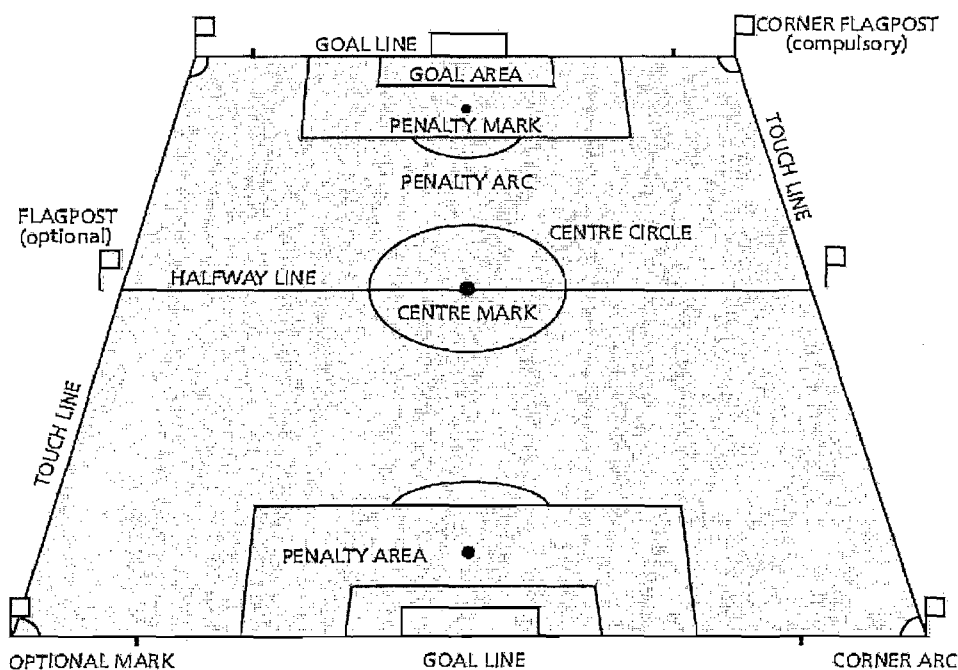
played informally, without field markings or real goals. In many places, the game is played barefoot using rolled-up rags or newspapers as a ball. Soccer is the world's most popular sport, played by people of all ages in about 200 countries. The sport has millions of fans throughout the world (Encarta, 2007).

In the United States, Canada and South Africa the game referred to as 'soccer'. Outside these countries the sport is commonly called 'football', or 'fútbol' in Spanish-speaking countries, where the game is particularly popular. The official name of the sport is 'association football'. The word 'soccer' is a slang corruption of the abbreviation 'assoc'. The Federation Internationale de Football Association (FIFA) is the worldwide governing body of soccer. FIFA governs all levels of soccer, including professional play, Olympic competitions, and youth leagues. The organization also governs the sport's premier event, the World Cup, an international competition held every four years pitting national teams from 32 countries against one another (Encarta, 2007).

2.2.1 The Field of Play

According to the official rules of FIFA (FIFA, 2007) the game may be played on a natural or artificial surface as long as it is rectangular. The length of the field must range between 90m and 120m and the width between 45m and 90m. The length of the touch line must always exceed the length of the goal line. The field must also be clearly demarcated with lines. These lines indicate the boundaries, the goal area, the penalty area and halfway way line with a centre circle in the middle. Figure 2.1 shows the field of play with the various lines.

Figure 2.1 The field of play (FIFA, 2007)



2.2.2 The Ball

The ball is spherical and made out of leather or any other suitable material. Its circumference must be between 68cm and 70cm with a weight between 410g and 450g and pressure equal to 0.6 to 1.1 atmospheres of pressure at sea level (FIFA, 2007).

2.2.3 The Players

A match is played between two teams containing no more than 11 players, one of whom is the goalkeeper. A match may not start if either team consists of fewer than seven players. In official matches organised under the auspices of FIFA, the confederations or member associations, up to three substitutions may be made during the match. In other matches, up to six substitutes may be used, or even more, as long as both teams agree to the number and the referee is informed (FIFA, 2007).

There are four main positions in a soccer team: goalkeeper, defenders, midfielders, and attackers. Generally, teams play with three or four defenders. Defenders are the last line of defence between the goalkeeper and the opposing team. Their primary job is to thwart an opposing attack by winning control of the ball. Defenders then initiate their own team's attack, moving the ball in the other direction, up field, and passing it ahead (Encarta, 2007).

Three or four players called midfielders, or halfbacks, act as a link between defence and offence. Midfield is the most demanding position, as these players must master skills necessary both to defend and attack. Midfielders are also constantly moving, running from one end of the field to the other (Encarta, 2007).

Attackers, or strikers, are primarily responsible for scoring goals. Teams generally play with two, three, or four forwards. Strikers must handle the ball well and be excellent passers, and they also must be exceptionally quick (Encarta, 2007).

Teams align their players in strategic formations that are described numerically. In the early days of soccer, the most common formation featured two defenders, three midfielders, and five forwards (2-3-5). As the game has developed, teams have assigned more emphasis on defence. In the modern game, most teams use the 4-4-2 formation (four defenders, four midfielders, two forwards). Other variations include the 3-5-2 formation (three defenders, five midfielders, two forwards), 4-3-3 formation (four defenders, three midfielders, three forwards) or 5-3-2 formation (five defenders, three midfielders, two forwards). Regardless of the official formation a team uses, any

player may be called upon to attack or defend at any time during a game (Encarta, 2007).

2.3 THE HISTORY AND ORIGINS OF SOCCER

According to Gerhardt (2004) the contemporary history of soccer spans more than a hundred years and began in England in 1863 when rugby football and soccer branched off from each other and the world's first football (soccer) association was founded. This first association was The Football Association in England. Both forms of the game seem to stem from a common root: Their early history reveals at least six different games back to which the origins of the game could be traced. Playing games with the feet has been going on for thousands of years.

Both Gerhardt (2004) and Tenemeza (2005) agree that one of the earliest forms of playing ball with feet was in China. 300 to 400 years BC the military in China had a test of skill called "Ts'uh Kuh" where the participants were required to kick a leather ball filled with feathers and hair through an opening measuring only 30-40cm in width. A variation of the game included the participant having to kick the ball into the net while withstanding attacks from opponents. Soccer-info (2000) states that the ancient Greeks and Romans also used football games to sharpen warriors for battle and in South and Central America a game called "Tlatchi" once flourished.

Another form of the game also existed in Japan about 600 years later, which is still played today. This game, called Kemari, is a type of circular game where the ball was passed between players without having it touch the ground (Tenemeza, 2005; Gerhardt, 2004). This is still practised at training sessions in the modern day.

The most common game that was played in the British Isles from the 8th to 19th century was disorganised, violent and spontaneous and was played by an indefinite number of players, usually from two opposing villages. Kicking was allowed, as well as almost everything else (Gerhardt, 2004). This ancestral game to both soccer and rugby commenced when the ball or similar object was thrown into the centre of the assembled “players” to start the game. Thereafter it was likely that anything was acceptable, since there were few, if any, rules governing the game. There were no restrictions on clothing, equipment, the number or age of participants or modes of transport during play. It was believed that some players participated on horseback, some carried swords and many carried staves. Drownings and ambushes were common, as rivals took the opportunity to settle simmering feuds and other private animosities (Noakes & Du Plessis, 1996:10).

During Elizabethan times there was a passion for football and it was often banned for being frivolous or causing public disturbances. Richard Malcaster, head of the famous Merchant Taylor’s school pointed out that the game had a positive educational value and promoted health and strength. He did, however, claim that it needed some refinement such as limiting the amount of players and a stricter referee. Cities like Venice and Florence in Italy had their own, more organised, form of the game during this time, known as “Calcio” It was more refined and teams were dressed in specific uniforms and it was played on certain holidays in Florence (Gerhardt, 2004).

In October 1863, eleven clubs sent representatives to the Freemason’s tavern in London to clarify the rules that govern matches. The dispute concerning shin-kicking, tripping and carrying the ball was discussed at consecutive meetings and on 8 December 1863 the die-hard elements of rugby were removed from the game,

finalising the split between rugby and soccer. The FA (English Football Association) was born and eight years later it already had 50 member clubs (Soccer-Info, 2000).

After The English Football Association, the next oldest was the Scottish FA (1873), the FA of Wales (1875) and the Irish FA (1880). The next countries to form football associations after Netherlands and Denmark in 1889 were New Zealand (1891), Argentina (1893), Chile (1895), Switzerland and Belgium (1895), Italy (1898), Germany and Uruguay (1900), Hungary (1901) and Finland (1901). FIFA was founded in Paris in May 1904 and it had seven founding members, namely: France Belgium, Denmark, Netherlands, Spain, Sweden and Switzerland. In 1912, 21 national associations were affiliated to FIFA. With the playing of the first World cup in 1930, there were 41 members of FIFA. At present, FIFA has 204 members all over the world (Gerhardt, 2004).

2.3.1 The History of South African Soccer

Soccer in South Africa goes back to the late nineteenth century when the game was brought to the country by British settlers. The first documented soccer matches took place in 1862 between civil servants and soldiers in Cape Town and Port Elizabeth. In 1879, the first ever recognised club, Pietermaritzburg County, was formed. After this, more clubs were born and the Natal Football association was formed in 1882 (Mazwai, 2003).

In 1892 the whites-only South African Football Association (FASA) was formed. Ten years later, the South African Indian Football Association (SAIFA) was founded in Kimberley. In 1932, the South African African Football Association (SAAFA) was

formed, followed the next year by the formation of the South African Bantu Football Association (SABFA) and the South African Coloured Football Association (SACFA). In 1951, SAIFA, SAAFA and SACFA formed the anti-apartheid South African Soccer Federation. In 1952, FASA was admitted to FIFA. In 1958 SABFA affiliates with FASA and FIFA recognises FASA as the sole soccer governing body in South Africa (Alegi, 2004).

In 1959 a landmark agreement was reached between the SABFA and FASA, where the aim is the creation of non-racial soccer matches in the future. The following year, however, South Africa was expelled from the inaugural Confederation of African Football (CAF) Cup in Egypt, due to insisting on sending an all white team (Mazwai, 2003).

In the same year, Women's soccer started in earnest in South Africa. FIFA suspended FASA in 1961, but lifted the suspension in 1963. FIFA then re-imposed the suspension in 1964 and in 1976 South Africa was formerly expelled from FIFA for practicing racial discrimination and for its representation of the minority whites only. Back in South Africa, the first multi racial National Premier Soccer League was ironically won by Lusitano, a Portuguese controlled club in 1978 (Mazwai, 2003).

On 8 December 1991, the non-racial South African Football Association (SAFA) was founded and this body was admitted to FIFA a year later. 1992 also marked the re-organisation of local domestic soccer with non-racial, democratic principles (Alegi, 2004).

After the return to international soccer, the South African national team was soon considered the “whipping boy” of African football, losing 4-0 to both Zimbabwe and Nigeria in 1992. After some re-organisation of the coaching structures, the team opened the 1994 season with a 1-0 defeat of Zimbabwe under coach Clive Barker. After the withdrawal of Kenya as host nation of the African Cup of Nations, the Tournament was relocated to be hosted by South Africa in 1996 (Mazwai, 2003)

As hosts, South Africa won the African Nations’ Cup by beating Tunisia 2-0 in the final at the FNB stadium in Johannesburg. In 1998, the South African National Team, now nicknamed Bafana Bafana, took part in the Soccer World Cup for the first time. In 2004 FIFA announced that the Soccer World Cup was to be presented in South Africa in 2010, a first for the African continent (Alegi, 2004).

2.4 SOCCER EPIDEMIOLOGY

Existing literature concerning soccer epidemiology will now be examined. The aim of this is to note patterns of occurrence and anatomical areas most affected, which will be used when creating a relevant test battery. Coggon, Rose and Barker (2003) define “Epidemiology” as the study of how often disease occurs in different groups and the reasons for these diseases. Epidemiological information is used to plan and evaluate strategies to prevent illness and as a guide to the management of patients in whom disease has already developed.

This study will examine the occurrence of soccer injuries amongst a population of youth soccer players. In order for the study to be effective, one must evaluate existing research to note injury trends and occurrence patterns, occurrence rates and general

design issues of studies. To create a preventative programme for soccer injuries, which is one of the sub-aims of this study, existing soccer injury research needs to be examined thoroughly. A variety of different studies must be examined to obtain a global overview of existing soccer epidemiological research for all playing groups. This chapter will examine research on professional men's soccer, women's soccer, amateur men's soccer as well as youth soccer and combinations of different codes of soccer. There is very limited research available on South African soccer epidemiology and this study aims to expand this lacking literature situation.

2.4.1 Epidemiology in Professional Male Soccer

Injury epidemiological research on professional male soccer will now be examined to determine injury prevalence and to determine anatomical areas most affected along with the main causes of these injuries.

Waldén, Häggelund and Ekstrand (2005a) conducted research on players from 11 professional clubs taking part in the UEFA league during the 2001-2002 season. These clubs represented England, France, Italy, The Netherlands and Spain. In total, 266 players were monitored in this research project. Exposure to matches and training was recorded for each player and injuries were recorded on a standardised form by club medical personnel. The total exposure for the involved players was 69 707 hours, of which 58 149 were training hours and 11 558 match hours. 85% of the players incurred injuries during the season, with a total of 658 injuries being recorded. This gave an injury incidence of 9.4 injuries/1000 player hours. Training injuries occurred at a rate of 5.8/1000 player hours and match injuries at a rate of 30.5/1000 player hours. 85% of the total injuries were of the lower limb. 5.5% of injuries were of the

foot, 14% of the ankle, 11% of the lower leg, 20% of the knee, 23% of the thigh and 12% of the hip and groin. Lower back injuries accounted for another 6% of injuries. 61% of the injuries were described as overuse injuries. Injury absence from play was recorded at an average of 13 days per injury. A comparison of the injury studies in male professional football can be seen in table 2.1.

Waldén, Häggelund & Ekstrand (2005c) made use of 310 soccer players from 14 teams in the Swedish top division to undertake epidemiological injury research. Total exposure of all the players involved in this study was 93 353 hours, with 81 801 hours being training hours and 11 552 being match hours. In total, 77% of the players incurred injuries during the season. A total mean injury rate of 8.3 injuries/1000 player hours was noted, with a match injury rate of 27.2 injuries/1000 player hours and a training injury rate of 5.7 injuries/ 1000 player hours. 87% of the injuries were of the lower limb. This is similar to the injuries recorded by Waldén *et al.* (2005a). 8% of the injuries were of the foot, 10% were of the ankle, 15% of the lower leg, 16% of the knee, 23% of the thigh, 16% of the hip/groin area and 6% were of the lower back. Over-use injuries constituted 37% of injuries and 22% of injuries were as a result of re-injury. The mean amount of time lost per injury was 13.8 days.

Häggelund, Waldén and Ekstrand (2003) compared the injuries recorded in the Swedish 1982 elite soccer season with the 2001 season described in Waldén *et al.* (2005c). In the 1982 season, 12 teams were monitored, consisting of 180 players. 76% of players incurred injuries during the 1982 season. These injuries occurred at a rate of 8.3 injuries/1000 player hours with rates of 4.6 injuries/1000 training hours and 20.6 injuries/1000 match hours being recorded. The injuries for the 1982 season were

not recorded for different body regions. It can be seen that the total injury rate recorded for the 1982 and 2001 seasons was similar (both 8.3 injuries/1000 hours).

Waldén, Häggelund and Ekstrand (2005b) compared the injury incidence and distribution amongst professional Danish and Swedish soccer players in the 2001 season. The Swedish injuries were described in Waldén *et al.* (2005c). A total of 188 Danish players from 8 teams in the top league were included in the research. A total of 27 321 hours of play were recorded with 23 095 hours in training and 4 226 hours in matches. 81% of players recorded injuries during the season. A total injury rate of 14.4 injuries/1000 player hours was recorded with a training injury rate of 11.8 injuries/1000 training hours and a rate of 28.2 injuries/1000 match hours. 89% of injuries were of the lower limb, with 7% of injuries being of the foot, 13% of the ankle, 11% of the lower leg, 21% of the knee, 22% of the thigh, 15% of the hip and groin and 7% of the back. 39% of injuries were as a result of over-use.

A study on injury epidemiology in four professional English soccer clubs was done by Hawkins and Fuller (1999). This study recorded the 1994-1997 seasons. The overall injury rate was 8.5 injuries/1000 player hours with 27.7 injuries/1000 match hours and 3.5 injuries/1000 training hours. A total of 86% of the injuries were of the lower limb. Of these, 6% of injuries were of the foot, 17% of the ankle, 13% of the lower leg, 14% of the knee, 23% of the thigh and 14% of the hip and groin. Only 8% of injuries were described as overuse injuries.

A comprehensive study was conducted on 91 English professional football clubs by Hawkins *et al.* (2001). This study was conducted over a two season period, spanning

from 1997 to 1999. A total of 2 376 players were involved in the research. Unfortunately, player exposure was not recorded during this time. A total of 6030 injuries were recorded in the two seasons, with an average of 24.2 days of play being missed per injury. Lower limb injuries accounted for 87% of all injuries recorded in the study. Of these, 6% of injuries were of the foot, 17% of the ankle, 12% of the lower leg, 17% of the knee, 23% of the thigh and 12% of the hip and groin. Of the total injuries, 58% were recorded as being non-contact injuries.

Chougle, Batty & Hodgkinson (2005) recorded injuries over a five season period at the Blackburn Rovers football club in England. Injuries were recorded from 1998 to 2004. 483 injuries were recorded in 91 players. Of these injuries, 92% of were of the lower limb. 3% of injuries were of the foot, 11% of the ankle, 16% of the lower leg, 16% of the knee, 27% of the thigh and 13% of the hip and groin. Exposure was not recorded during this study. The amount of time missed due to injury had a mean value of 15 days. 27.5% of injuries were regarded as overuse injuries.

During the inaugural season of the United States Major Soccer League, Morgan and Oberlander (2001) recorded 399 injuries in the 237 players that were monitored for injuries. These players were from the 10 teams that competed in the league. An injury rate of 6.2 injuries/1000 hours was recorded. Match injuries occurred at a rate of 35.3 injuries/1000 match hours and training injuries at 2.9 injuries/1000 playing hours. Of the total injuries, 77% were of the lower limbs. The players involved in this study ranged from 18 to 38 years of age. Twenty one percent of injuries involved the knee and 18% involved the ankle.

Table 2.1 Comparison of injury studies on male professional soccer players

	Waldén <i>et al.</i> (2005a)	Waldén <i>et al.</i> (2005b)	Waldén <i>et al.</i> (2005c)	Häggelund <i>et al.</i> (2003)	Hawkins & Fuller (1999).	Hawkins <i>et al.</i> (2001).	Chougale <i>et al.</i> (2005)	Morgan & Oberlander (2001)
Injury Rate	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours
Total	9.4	14.4	8.3	8.3	8.5	*	*	6.2
Match	30.5	28.2	27.2	20.6	27.7	*	*	35.3
Training	5.8	11.8	5.7	4.6	3.5	*	*	2.9
Area	% of total	% of total	% of total	% of total	% of total	% of total	% of total	% of total
Lower Limb	85	89	87	*	86	87	92	77
Foot	5.5	7	8	*	6	6	3	*
Ankle	14	13	10	*	17	17	11	18
Lower leg	11	11	15	*	13	12	16	*
Knee	20	21	16	*	14	17	16	21
Thigh	23	22	23	*	23	23	27	*
Hip and Groin	12	15	16	*	14	12	13	*
Overuse	27	39	37	*	8	58 #	27.5	*
Days missed	13	11.8	14	*	*	24.2	15	8

* = Not available # = non contact injuries

Deehan *et al.* (2007) report that the incidence of injuries in English professional soccer is approximately 1.3 injuries per player per season, resulting in a mean loss of 22 days of training and competition per year. A review by Wong and Hong (2005) showed an injury rate of between 6.2 injuries/1000 player hours and 12.4 injuries/1000 player hours in professional football literature that was reviewed.

From the research done on professional male soccer, it can be seen that all the studies are in agreement that the lower limb is the body part that is most often injured during play, accounting for between 77% and 92% of all injuries. Injury rates in professional soccer ranges between 6.2 and 14.4 injuries/1000 playing hours. Match injury rates (between 20.6 and 35.3 injuries/1000 hours) are much higher than the rate of those

occurring during training (between 2.9 and 11.8/1000 hours). The number of non contact injuries recorded in these epidemiological studies ranged between 8% and 58% of the total injuries.

These findings can lead us to the following conclusions: as the majority of soccer injuries occur in the lower limb, any injury prevention should be aimed at this body area. Injury rates are much higher in matches than in training and could be due to the higher intensity of match play. The intensity of training could possibly be increased, to better prepare players for match conditions and thus possibly lower the injury rate in matches. The causes of non contact injuries need to be found, as this high number of injuries (ranging between 8% and 52%) could possibly be reduced by preventative training programmes. This study aims to examine the causes of these non-contact injuries and develop a preventative training programme to address them.

2.4.2 Epidemiology in Amateur Male Soccer

As amateur soccer and professional soccer differ in intensity and exposure, it is important to also examine whether differences exist between the two codes of play. There is, however, very limited research available on the occurrence of injuries amongst amateur players. Epidemiological rates are not widely available and only the types of injuries could thus be compared to professional soccer.

Twizere (2004) conducted a study on injury occurrence amongst 30 male amateur teams from the first and second divisions of the Rwanda soccer league. Of the 30 teams, 14 were from the first division and 16 from the second division. A total of 900 players formed part of these teams. A random sample of each team was chosen to

complete a retrospective injury questionnaire on injuries sustained during the previous season. This research showed that 85.7% of the reported injuries were of the ankle and the knee. Sprains were the highest occurring type of injury with 26% of the total. Contusions accounted for 21% of injuries and fractures for a further 13%. Poor pitch conditions was reported as one of the main causes of injuries along with a violent game and over-training. Overuse is also cited as one of the other causes of injuries along with lack of rehabilitation, lack of endurance congested calendar and lack of team medical personnel. Players from the first division also showed higher injury rates than second division players, once again pointing to the fact that the level of intensity has an effect on injury occurrence.

Gonga and Gongal (2003) recorded amateur soccer injuries reported at King Edward VIII Hospital in Kwazulu-Natal between January 1999 and August 2002. In this time, 32 severe injuries were recorded. These included 18 fractures of the tibial and femoral shafts. In the same time, 122 other injuries were also recorded. Soft tissue injuries of the knee (29%) and soft tissue injuries of the ankle (30%) were the majority of these injuries. 9% of the injuries were soft tissue injuries of the thigh and hip and a further 10.6% of the injuries were soft tissue injuries of the leg. Although a proper epidemiological study was not done, this study does show that serious injuries do occur in South African amateur soccer and that urgent steps need to be taken to prevent these injuries. The majority of injuries (85%) recorded in this study were shown to be soft tissue injuries. The level of severity of the injuries was quite high, as minor injuries rarely necessitate a hospital visit.

Bailey, Erasmus, Luttich, Theron and Joubert (2009) published injury prevalence research conducted on the first soccer team from the University of the Free State. The study was conducted on 16 players, with the mean age not being supplied. The players are assumed to be between 19 and 23 years old, as this is a university team. The team was observed for the duration of the season at matches and all match injuries were recorded. 15 injuries were recorded in 23 matches during the season. The match injury rate was 39.5 injuries/1000 match hours. Ankle injuries were the most common, with 47% of the total. Knee injuries accounted for 27% of injuries. 60% of all injuries were sprain type injuries.

It can be seen in both professional and amateur soccer, the lower limb is the area with the highest injury prevalence. The knee and ankle are the body areas which incur the highest percentage of injuries. Soft tissue injuries accounted for the most injured anatomical structures. One study also points overuse out as a leading cause of injuries. This shows further evidence that preventative research should focus on lower limbs

2.4.3 Epidemiology in Female Soccer

In order to gain a wider knowledge and overall perspective of soccer injuries, women's soccer epidemiology will now also be examined. This will be done to determine whether there are similarities between the epidemiology of men's and women's soccer and whether similar areas are most often injured and whether injury causes are similar between the different sexes in soccer. When the aim is to create a preventative programme and prediction model, it is important to note injury patterns all across the spectrum of soccer and all represented players.

Jacobsen and Tegner (2006) conducted research on all 12 female teams of the premier soccer league in Sweden. A total of 269 players took part in the study. Of the 269 players, 48% were injured during the season, incurring a total of 237 injuries. A total injury incidence rate of 4.6 injuries/1000 player hours was noted, with match injuries occurring at a rate of 13.9 injuries/1000 match hours and a training rate of 2.7 injuries/1000 training hours. 82% of the recorded injuries were of the lower limb. Of the total injuries, 6% were of the foot, 10% were of the ankle, 13% were of the lower leg, 24% were of the knee, 20% were of the thigh and 10% were of the hip and groin. 31% of injuries were classified as overuse injuries. A similar pattern is noted as in male players, with the lower limb being the area of highest injury and overuse injuries accounting for a large percentage (31.2%) of the recorded injuries.

Similar epidemiological research was done by Östenberg and Roos (2000) utilising 123 female players from 8 clubs in the Swedish league. Thirty-two of the participants were elite players and ninety one were non-elite. The injury rate during matches was 14.3 injuries/1000 match hours and during training, 3.7 injuries/1000 training hours. These rates are fairly similar to those of Jacobsen and Tegner (2006), who utilised a similar research population of Swedish women. Overuse injuries constituted 22% of the total injuries. Lower limb injuries accounted for 80.2% of all injuries. The foot made up 12.3% of all injuries, the ankle 10.8%, the leg 6.2%, the knee 26.2%, the thigh 17% and the groin 7.7%.

The injury data from the first two seasons of the Women's United Soccer Association was analysed by Giza, Mithöfer, Farrel, Zarins & Gill (2005) to determine injury epidemiology. Two hundred and two players were involved in the study and 173

injuries were recorded. The total injury rate was 1.93 injuries/1000 player hours. Injuries had a rate of 1.17 injuries/1000 training hours and 12.63 injuries/1000 match hours. Most of the injuries (60%) were of the lower limb. Although the lower limb is still the area with the most injuries, this is substantially lower than other studies on female players (Jacobson & Tegner, 2006; Lilley, Gass & Locke, 2002; Östenberg & Roos, 2000). Knee injuries were the most common injuries at 31.8%, followed by head injuries (10.4%), ankle injuries (9.3%) and foot injuries (also 9.3%).

Lilley *et al.* (2002) conducted a five year (1993-1998) retrospective injury survey with 45 elite female players from the Queensland Academy of Sport in Australia. The study recorded 239 injuries. In 1993, the incidence rate was 10.9 injuries/1000 player hours. In 1994, the rate increased to 12.2 injuries/1000 player hours. In 1995 there was a substantial drop to 5.0 injuries/1000 player hours. 1996, 1997 and 1998 had injury rates of 6.6/1000 hours, 5.5/1000 hours and 6.7/1000 hours respectively. Lower limbs accounted for 81.5% of the total injuries. Ankle injuries constituted 24% of all injuries, lower leg injuries 24%, knee injuries 12%, foot injuries 10%, thigh injuries 7% and hip injuries 4%. Once again, lower limb injuries are the most abundant, as in other studies of male and female soccer. Strains (35%) and sprains (31%) were the most common types of injuries.

Faude, Junge, Kindermann and Dvorak (2005) conducted similar epidemiological research on female soccer players in Germany. A total of 165 players from the German national female league were included in this research. Exposure was recorded by trainers, and physiotherapists recorded all the injuries occurring during a single outdoor soccer season. Two hundred and forty one injuries were sustained by 115

players during this season. Injuries occurred at a rate of 23.3/1000 match hours and 2.8/1000 hours of training. As with the other studies, the majority of injuries (80%) were of the lower limb. Sixteen percent of the injuries were classified as overuse injuries and a further 47% of the injuries were classified as non contact traumatic injuries. Preventative programmes generally aim at reducing these overuse and non contact injuries, which would then considerably lower the total number of injuries.

Engstrom, Johansson & Tornkvist (1991) also conducted epidemiological research using female soccer players from Stockholm, Sweden. Forty one players from two teams took part in the study. One team was from the premier division and the other from the second division. This study showed that 88% of injuries monitored during a one season observational period were of the lower limb. Match incidence of injuries was 24/1000 match hours and that of training was 7/1000 hours. The combined total was 12 injuries/1000 playing hours. Sprains (33%) and tendonitis/bursitis (24%) were the types of injuries that occurred most often. The ankle (26%), knee (23%) and thigh (15%) were the body areas that were most injured. Engstrom *et al.* (1991) also recommend in this study that the majority of overuse injuries could probably be prevented by changes in the character of training.

Table 2.2 Comparison of injury studies on female soccer players

	Jacobson & Tegner (2006)	Östenberg & Roos (2000)	Giza <i>et al.</i> (2005)	Lilley <i>et al.</i> (2002)	Faude <i>et al.</i> (2005)	Engstrom <i>et al.</i> (1991)
Injury Rate	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours
Total	4.6	*	1.93	5.0 -12.2	*	12
Match	13.9	14.3	12.63	*	23.3	24
Training	2.7	3.7	1.17	*	2.8	7
Area	% of total	% of total	% of total	% of total	% of total	% of total
Lower Limb	82	80.2	60	81.5	80	88
Foot	7	12.3	8	10	11.2	9
Ankle	13	10.8	8	24	17.8	26
Lower leg	11	6.2	5	24	8	9
Knee	25	26.2	31.8	12	21.2	23
Thigh	19	17	3	7	18.25	15
Hip and Groin	7	7.7	4.2	4	5	6
Overuse	31.2	22	16	*	16	*

* = Not available

Injury rates in women's soccer ranged from 1.93 injuries/1000 players hours to 12.2 injuries/1000 player hours, which is lower than the rate recorded for male players. This is contrary to the statement by Lilley *et al.* (2002). This could possibly be attributed to the outdated nature of the comparative literature used by Lilley *et al.* (2002). Lower limb injuries constituted between 60% and 88% of injuries. This is similar to the high percentages noted in male players. Match injury incidences for all the studies on female players were similar, ranging between 12.63 injuries/1000 match hours and 24 injuries/1000 match hours. Overuse injuries ranged between 16% and 31.1% of the total injuries, which is also similar to studies on male players. It can be seen that there are similar injury trends that were recorded amongst male and female players and that injury prevention models would thus need to address similar types of injuries and injury related problems. Engstrom *et al.* (1991) makes the

important observation that the majority of overuse injuries could probably be prevented by changing the character of training.

2.4.4 Epidemiology in Youth Soccer

Literature regarding soccer injury epidemiology amongst youth players will now be examined. This literature is of vital importance, as the current study will be focusing on the prevention of injuries amongst youth players, and comparative studies need to be used for epidemiological background. It is therefore of vital importance to note injury patterns and prevalence amongst youth players, as this will have a definitive influence on the design of any prevention programmes and the prediction model proposed in the current study.

In research conducted on 496 youth soccer players from 3 clubs in Denmark, Schmidt-Olsen, Jorgenson, Kaalund and Sorensen (1991) reported an injury rate of 3.7 injuries per 1000 player hours. This research was. The players were between the ages of 12 and 18 years. During the season of injury monitoring, 312 injuries were recorded. The majority of the injuries (70%), were of the lower limb. The knee (26%) and ankle (23.1%) were the body areas with the highest injury occurrence. Back pain accounted for 14% of the injuries. The injury rate increased as the age of the players increased. Players between 12 and 13 years of age had an injury rate of 3.4/1000 hours while players between 17 and 18 years of age had an injury rate of 4.0/1000 player hours. Schmidt-Olsen *et al.* (1991) suggest that a possible cause for youth injury rates being lower than senior injury rates could be ascribed to better flexibility and less weight and speed during collisions.

Price *et al.* (2004) collected injury data from 38 English football club youth academies over a two season period. All registered players between the ages of 9 and 19 years were included in the research. A total of 3 805 injuries were recorded in this two season period with an average of 0.4 injuries per player per season. The average time spent off play was 21.9 days. This time off equated to about 6% of the player's development time. The incidence of injuries was higher in the 17 to 19 year old age group when compared to 13 to 16 year olds. Non contact injuries made up 34% of the total injuries monitored in this study. Strains, sprains and muscular contusions accounted for 31%, 20% and 8% of all injuries respectively. The lower limb was the anatomical area with the most injuries, accounting for 90% of all injuries during the two seasons. On closer examination of these lower limb injuries, the thigh accounted for 19% of all injuries, the ankle 19%, the knee 18%, the lower leg 10%, the hip and groin 12%, the foot 8% and the lumbar spine 4%.

Deehan *et al.* (2007) assessed injuries to all the youth players at the Newcastle United Football academy over a five year period. Two hundred and ten players between the ages of 9 and 18 years were monitored. Similar to senior players, the largest percentage of injuries was of the lower limb, namely 79%. Non-contact injuries accounted for 69% of injuries. During the five year period of the study, a total of 685 injuries were monitored. Of these, 6.5% of injuries were of the groin and 79% to the lower limb. Combining these two areas gives a percentage of 85.5% of the total injuries, which is similar to the findings of Price *et al.* (2004). Incidence of injuries in these youth players was 0.6 injuries per player per season. 76% of the injuries monitored during this study were soft tissue injuries. Strains made up 37% of the total

injuries, sprains 18% and muscular contusions 5.8%. These findings are similar to those of Price *et al.* (2004).

Junge *et al.* (2004) did a comparative study between New Zealand youth rugby and soccer players. Twelve school teams ranging in age from 14 to 18 years participated in this research lasting one season. The study included 145 soccer players and 123 rugby players. A total of 261 soccer injuries were noted during the season, resulting in an average of 1.8 injuries per youth soccer player per season. 14.9% of the soccer injuries were classified as overuse injuries. In this cohort of youth soccer players, 77% of the injuries were of the lower limb. When the injuries are separated into anatomical regions, the hip and groin area accounted for 9.3% of injuries, the thigh 17.0%, the knee 15%, the lower leg 16.1%, the ankle 17.2% and the foot 5.8%. As far as injury rate is concerned, training injuries occurred at a rate of 15.4 injuries/1000 training hours and match injuries occurred at a rate of 47.5 injuries/1000 match hours. Strains made up 31.8% of the soccer injuries, sprains 20.3% and contusions 28.4%.

An injury prevalence study on French elite youth soccer players was done by Le Gall, Carling, Reilly, Vanderwalle, Church and Rochcongar (2006), using data collected over a 10 season period. Players of the U/14, U/15 and U/16 year age groups were used. U/14 players showed a total injury incidence of 4.9 injuries/1000 player hours of which the match rate was 9.5 injuries/1000 hours and training injuries had a rate of 4.1 injuries/1000 training hours. In the U/15 group the total injury rate was 4.6 injuries/1000 player hours with a match rate of 10.4 injuries/1000 match hours and a training rate of 3.7 injuries/1000 training hours. The U/16 age group showed a total injury rate of 5.2 injuries/1000 player hours. The match rate was 14.2 injuries/1000

match hours and the training rate 3.8 injuries/1000 training hours. Lower limb injuries accounted for 70.7% of all injuries. The upper leg, ankle and knee were the most injured individual anatomical areas with 24.5%, 17.8% and 15.3% of all injuries respectively. This study showed that contusions were the most common type of injury (30.6%). Sprains constituted 16.7% of injuries and strains 15.3% of injuries.

Leininger *et al.* (2007) reported on paediatric soccer injuries reported at the casualty departments of 100 hospitals in the USA. This study stretched over a thirteen year period between 1990 and 2003. A total of 1 597 528 paediatric soccer injuries were recorded during this period. The lower extremity accounted for 45.9% of the reported injuries. Most studies show that lower limb injuries range between 70% and 90% of all injuries, suggesting that although the lower limb is the most injured body region, little more than half of these injuries are serious enough to seek emergency medical care in a hospital. The high percentage of upper limb injuries reported at the emergency departments (30.9% of the total), indicates that although upper limb injuries might generally be less in number in soccer injury studies, they are more severe and require emergency medical care more often. Strains and sprains were the injuries with the highest occurrence with a combined percentage of 34.0% of the total injuries. Contusions and abrasions accounted for 23.0% of the total injuries.

The influence of player-to-player contact in boys' youth soccer on injuries was examined by Schwebel, McDaniel and Banaszek (2006). Their research shows that although a large number of player-on-player contacts took place during one season of youth soccer in under 11 and under 12 boys, less than 1% of these collisions resulted in injury. This leads us to the conclusion that player contact does not have a large

influence on youth soccer injuries and other causes for injury need to be investigated and preventative steps need to be taken to reduce these causes.

Emery and Meeuwisse (2006) did a comparative study between the injury rates of indoor and outdoor youth soccer. The outdoor cohort consisted of 153 male players and the indoor cohort of 67 male players. Observations of injuries were done over a one season period for both indoor and outdoor soccer. The players ranged between under 14 and under 18 year age groups. Lower limb injuries accounted for 85.71% of injuries in the outdoor season and 78.21% of injuries in the indoor season. The ankle and knee were the most injured body parts during the outdoor season and the ankle and groin were the most injured during the indoor season. The total injury rate during the outdoor season was 4.45 injuries/1000 player hours and during the indoor season 5.59 injuries/1000 playing hours. Direct contact accounted for 60% of injuries in indoor soccer and 46% of injuries in outdoor soccer. This study argues that previous injury seems to be one of the most direct risk factors for injuries incurred in youth players.

Table 2.3 Comparison of injury studies on youth soccer players

	Price <i>et al.</i> (2004)	Deehan <i>et al.</i> (2007)	Junge <i>et al.</i> (2004)	Le Gall <i>et al.</i> (2006)	Schmidt-Olsen <i>et al.</i> (1991)	Emery & Meeuwisse (2006)
Injury Rate	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours
Total	*	*	27.9	4.8	3.7	4.45-5.59
Match	*	*	47.5	11.2	*	*
Training	*	*	15.4	3.9	*	*
Days lost	21.9	22	*	32	*	*
Injuries per player season	0.4	1.3	1.8	*	0.63	*
Area	% of total	% of total	% of total	% of total	% of total	% of total
Lower Limb	90	79	80.4	70.7	70	78%-85%
Foot	8	*	5.8	8.2	0.3	*
Ankle	19	*	17.2	17.8	23.1	*
Lower leg	10	*	16.1	5.2	10.9	*
Knee	18	*	15	15.3	26.0	*
Thigh	19	*	17	24.5	*	*
Hip and Groin	12	6.5	9.3	7.1	8.9	*
Overuse	*	69 #	14.9/ 50 #	17.3	*	*

* = Not available # = Non Contact

It can be seen from the various studies on youth soccer players that between 70.7% and 90% of all recorded injuries were of the lower limb, similar to adult male and female soccer. The injury rate per player per season range between 0.4 and 1.8 for these studies on youth players with an injury occurrence rate between 3.7 injuries /1000 hours and 27.9 injuries /1000 hours. Strains and sprains are generally the types of injury with the highest occurrence in youth soccer players. Between 14.9% and 69% of injuries were recorded as non-contact or overuse injuries. Price *et al.* (2004) recommend that strategies be implemented to try to reduce the number of strains, sprains and non-contact injuries that are prevalent in youth football. Deehan *et al.* (2007) further stress that the prevention of injury is crucial to minimising longer-term degenerative joint disease and persistent dysfunction in youth soccer players.

2.4.5 Summary of Epidemiology

In all the epidemiological research reported in this chapter, certain patterns are clearly visible through all codes of play, age groups and sexes. The lower limb is the area which sustains the most injuries at all levels of play. Youth players show figures of 70% to 90%, females 60% to 82% and males 85% to 92%. Injury prevention should thus be focused on this area of the body. Overuse and non contact injuries also amount to a large percentage of all injuries. These injuries could possibly be avoided by taking preventative measures and Engstrom *et al.* (1991) observes that the majority of overuse injuries could probably be prevented by changing the character of training. Price *et al.* (2004) recommend further research to evaluate the exposure to injuries at youth level, which this study will also do. Le Gall *et al.* (2006) state that players from all age groups are more at risk of sustaining injuries, and especially overuse disorders, during the first few competitive months of the season. This literature review shows that soccer injuries on all levels of play and competition show similar trends, such as players who are more prone to injury at the beginning of the season, especially with overuse injuries, body areas injured and type of injuries. This theoretically makes creating universal preventative programmes and prediction models a possibility with strong evidence that pre-season screening could be used to try and determine deficiencies which may lead to injuries.

2.5 SUMMARY

This chapter contained, amongst others, literature examining and discussing the history and origins of soccer. The rules of the game are also explained. A literature study on current epidemiological research was done to determine injury patterns and occurrence in different player populations, to validify the focus of the injury

prevention programme and test battery. The next chapter will focus on literature examining the tests which would be considered for pre-season screening in this study. Current sports prediction and injury prediction will also be examined as well as statistical models used for prediction functions.

CHAPTER 3

LITERATURE REVIEW: TESTING PARAMETERS

- 3.1 INTRODUCTION**
- 3.2 CURRENT PREDICTION MODELS AND PREVENTATIVE STRATEGIES**
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CHAPTER 3

LITERATURE REVIEW: TESTING PARAMETERS

3.1 INTRODUCTION

In the previous chapter, it was determined that the lower limb is the most often injured area in all levels of competitive soccer, including youth soccer. Non-contact and overuse injuries were also found to represent a sizable percentage of all injuries occurring in youth players. This chapter will evaluate existing research on current prediction models and preventative measures. This research will then be used for the compilation of an appropriate test battery for the evaluation of youth soccer players and also substantiate the inclusion of the selected test parameters in the test battery used for this study. Further literature on biomechanics, plyometrics, proprioception and balance will also be examined, giving an in-depth background on the influence of these parameters on injuries and in so doing, validate the research design and the inclusion of the selected testing parameters.

One must also examine and explain the philosophy and reasons for testing subjects. According to Morrow, Jackson, Disch and Mood (2000) there are six purposes of measurement, testing and evaluation. These are placement, diagnosis, prediction, motivation, achievement and programme evaluation. Testing for placement purposes becomes necessary to place players in groups according to their biomechanical profile, where players with non-ideal profiles can then be placed on a training programme. Testing for diagnostic purposes helps us to identify weaknesses in players that could lead to injury at a later time or to identify current injuries. Testing

for predictive purposes is necessary to identify players at risk of injury due to shortcomings in their biomechanical profile, plyometric or balance abilities. Testing for motivational purposes is necessary to help participants to try and better themselves and to participate in any training programme to the best of their abilities. Testing also sets baseline standards to which future tests can be compared to determine achievements during training. Testing is also an important tool in evaluating the effectiveness of a training programme.

Testing in this study will be used for diagnostic and predictive purposes, using a pre-season evaluation to determine a player's risk of incurring injury during the season. In any research setting, it is important to evaluate the tools being used for assessment of test subjects as well as the significant influence of the test parameters on the outcome measures. After a thorough literature review on injury prediction and current preventative strategies, a research design was established, combining a biomechanical evaluation, plyometric strength ratios and a static balance test to form a pre-season evaluation battery for the purpose of pre-determining the possibility of, and susceptibility to, injury in any tested player.

3.2 CURRENT PREDICTION MODELS AND PREVENTATIVE STRATEGIES

In order to compile a predictive model for injury prevention purposes, current prediction models and injury prevention strategies need to be examined and evaluated. This will indicate which parameters have been included in existing models and identify shortcomings that should be addressed in further research. It will also identify parameters which have proven to be successful in prediction of injuries in other

sporting codes and research settings. These could then be included in test batteries for prediction of injuries in youth soccer players.

3.2.1. Current Prediction Models

Prediction models are also used for purposes other than injury prediction. Amongst soccer players, Badenhorst (1998) used functional discriminant analysis to discriminate between players with talent and players with less talent. U/17 soccer players were used in this research and the top team of the league was selected as talented players and the bottom team in the league as less talented. A total of 37 players were included in this research project. A prediction model was created, which could correctly place players into the talented or less talented group. This model was based on physical and psychological test parameters.

Predictive models were also used on youth soccer players by Gird (2005) for the purpose of determining talent amongst players. This research was conducted on 33 youth soccer players that were identified as talented, less talented and development players. Discriminant function analysis was then done to classify correctly the players into their respective groups based on a test battery containing Physical, Motor, Anthropometric and Sportpsychological parameters. Isokinetic ankle dorsiflexion and plantar flexion peak torque, hamstring suppleness, agility, percentage muscle mass, speed over five meters and trunk flexion strength were identified as variables that could be used to classify players correctly as talented or less talented.

Van Gent (2003) conducted research to determine the positional requirements for U/13, U/16, U/18 and U/19 rugby players with regard to anthropometric, game

specific, and physical and motor tests. North West provincial youth rugby players were used in this research. A prediction model was created to determine test values that could be used to discriminate between players of different playing positions. In U/19 players, vertical jump test values were identified as one of the values used to discriminate between tight forwards, loose forwards, scrum- and flyhalf and backline players. The other variables used for discrimination were: speed over 30m; ankle girth; ground skills and thigh girth.

Research was done by Hanekom (2003) to examine which were the best indicators for determining suitable conditioning programmes that would lead to improved performance of U/19, U/21 and senior elite club rugby players. This study showed that improvements in strength (bench press and squat), speed and agility were the best indicators of the success of a conditioning programme for performance improvement. Functional discriminant analysis was also used during this research to determine these indicators for successful conditioning programmes.

Research has also been done to determine which prediction functions are most effective at predicting group membership. Booysen (2002) used existing talent identification data from previous research to test the difference between logistic regression and functional discriminant analysis in predicting an individual player's inclusion in a group of talented or less talented U/12 rugby players. The research shows that both models are equally effective in determining group membership, but just go about the prediction in a different manner. Discriminant analysis provided an accurate view of the best discriminating factors involved in talent, while logistic

regression provides a view of the relative impact of the various factors determining talent.

Many current prediction models make use of regression statistical models. These models identify the relative impact that different test factors have on predicting group membership. This enables the prediction of the dependent variables and also provides an assessment of the relative impact of each of the independent variables. It also indicates the combined ability of the independent variables in explaining the variation of the dependent variable (being injured or not) (Booyesen, 2002). Firstly, the statistical basis of regression models will be examined and then current models will be evaluated.

3.2.1.1 Logistic Regression

The general purpose of multiple regression is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable. Researchers would then collect data on numerous variables possibly having an influence on the occurrence of injuries (Biomechanical evaluation, Plyometric strength and Proprioception). Those variables with the largest (standardised) regression coefficients are the ones that contribute most to the prediction of a group membership. The classification functions in multiple regression have the form: $D = a + b_1 * x_1 + b_2 * x_2 + \dots + b_m * x_m$, where a and the b 's are sets of constants determined for each group. The x 's are the variables which are selected in a stepwise manner such that it discriminates maximally between the groups (STATSOFT, Inc., 2003).

Logistic regression can be used to predict a dependent variable (In this case, whether or not a player will be injured) based on continuous independent, or predictor, variables to determine the percentage of variance in the dependent variable explained by the independents and also to rank the relative importance of the independents. The influence of predictor variables are usually explained in odds ratios. Logistic regression applies the maximum likelihood method of estimation, determining the odds of a certain event occurring (Garson, 2008).

According to Garson (1998), there are several purposes for Multiple Regression Analysis:

- To determine the most parsimonious way to distinguish among groups.
- To test theory by observing whether cases are classified as predicted.
- To determine the percent of variance in the dependent variable explained by the independents.
- To determine the percent of variance in the dependent variable explained by the independents over and above the variance accounted for by control variables, using sequential discriminant analysis
- To discard variables which are little related to group distinctions
- To infer the meaning of multiple regression analysis dimensions which distinguish groups, based on discriminant loadings.

3.2.1.2 Current Injury Prediction Literature

There are currently very few injury prediction models, and these models usually focus on only one or two physical parameters such as previous injury (Knowles, Marshall, Bowling, Loomis, Millikan, Yang, Weaver, Kalsbeek & Mueller, 2006; Kucera,

Marshall, Kirkendall, Marchak & Garret, 2005; Francis, Richman & Patterson, 1998), balance (McGuine *et al.*, 2000), core stability (Peate, Bates, Lunda, Francis & Bellamy, 2007) or muscle length (Debedo, White & George, 2004). Existing studies will now be discussed as a background for the basis of injury prediction on sports injuries and other settings.

Peate *et al.* (2007) conducted a battery of tests from a functional movement screen that evaluated muscle flexibility and trunk stabiliser muscles amongst 433 fire-fighters. The correlation between the functional movement screen and injuries was analysed. A further program that was created to enhance flexibility and core stability was also evaluated. Fire-fighters are classified as “industrial athletes”, due to their jobs often requiring maximal physical performance. The functional movement screen consisted of seven functional movements that assessed trunk and core strength; neuromuscular coordination; symmetry of movement; flexibility; acceleration; deceleration and dynamic stability. Each of these tests correspond with job specific demands placed on firemen. Logistic and Linear regression was used as statistical analysis and an intervention program was then created. The intervention reduced time lost due to injuries by 62% and the number of injuries by 42% over a twelve month period when compared to a control group.

In research conducted by Francis *et al.* (1998), 682 questionnaires were distributed to race walkers in California. Four-hundred questionnaires were returned and the data from these was examined using a Stepwise Discriminant Analysis to develop a prediction model for injuries in the sport of racewalking. The questionnaire contained questions relating to demographic information, exercise patterns, competitive history,

walking surface, type of footwear and injuries suffered during racewalking. A model based on the data from the investigation correctly predicted membership to either the injured or uninjured group in only 64.1% of the cases, making it of limited use to researchers and clinicians. This study did not, however, contain any elements of physical testing, which is an essential component of sports injury prevention.

Kucera *et al.* (2005) used injury history as a predictive factor for determining the risk of injury in youth soccer players. A total of 5 139 player seasons were followed up for injuries after 1 483 players returned previous history questionnaires. This study used Multivariate Generalised Regression modelling and indicated that players with one previous injury had a twofold greater risk of incident injury and those with two or more previous injuries had a threefold greater risk of incidence injury when compared with athletes without previous injury. Injury history was shown to be associated with an increased injury rate. Players aged 12 to 18 years from the classic league of the North Carolina Youth Soccer Association took part in this research.

Similar findings were made by Knowles *et al.* (2006) who reported on a prospective cohort study of injury risk factors for high school athletes from 12 sports in 100 North Carolina schools from 1996 to 1999. Intrinsic and extrinsic risk factors were recorded. The included risk factors were: sport, gender, grade, multisport participation, years of playing experience, prior injury, age, body mass index for age, competition division, coaching experience, -qualifications- and -training. After adjustment for other factors, having a prior injury was associated with a twofold increase in injury rate when compared with no injury. The highest incidence of injury was amongst football

players with male and female soccer the second highest. Males also had a higher injury incidence than females.

Kofotolis, Kellis and Vlachopoulos (2007) conducted a similar study to determine risk factors that influence the occurrence of ankle injuries amongst amateur soccer players. Three hundred and twelve players from 19 clubs in the Greek Amateur Association soccer league participated in this research project. Player injuries were prospectively monitored over a two year period. Age, height, training status, body mass and history of previous ankle sprain were considered further in a backward Stepwise Multivariate Logistic Regression analysis to evaluate as potential predictor values. The results from the regression analysis identified significance for the prediction of ankle sprains for history of ankle sprains. 60.5% of ankle injuries occurred in players with a history of previous ankle injury. This supports the findings of Kucera *et al.* (2005) and Knowles *et al.* (2006). All these findings suggest that history of injury should be considered when it comes to prediction models of soccer injuries.

Research by McGuine *et al.* (2000) will be discussed in detail later in this chapter. Logistic Regression Analysis was carried out to determine if gender, dominant leg and balance scores were related to ankle sprain injuries in basketball players. It was determined that preseason balance measurement served as a predictor of ankle sprain susceptibility. Subjects who had demonstrated poor balance had nearly seven times as many ankle sprains as subjects who had good balance.

A number of risk factors for soccer injuries were identified by Arnason, Sigurdsson, Gudmundsson, Holme, Engebretsen and Bahr (2004) using soccer players from the

two highest divisions in Iceland. A total of 306 male soccer players participated in the research. The following factors were examined prior to the 1999 soccer season: height, weight, body composition, flexibility, leg extension power, jump height, peak O₂ uptake, joint stability and history of previous injuries. For hamstring injuries, the significant risk factors were age and previous hamstring strains. For groin strains, the predictive risk factors were previous groin strains and decreased range of motion in hip abduction. Previous injuries were also identified as risk factors for knee and ankle sprains. Older players were also found to generally be at higher risk for injuries.

Sports injury risk factors were also examined by Watson (2001), using 102 players from soccer, Gaelic football and hurling over a two year period. Injuries were monitored and recorded during the first season. The subjects then underwent flexibility tests, postural assessment, measures of speed and acceleration and a clinical assessment of anatomical and physiological factors thought to be associated with risk of injury. Stepwise Multiple Regression Analysis revealed that days off due to injury in the second season could be predicted from the days of injury during the first season; posture; acceleration over 10m from standing and the number of musculoskeletal clinical defects. Flexibility scores were not found to be significant predictors of injury. It is suggested that injury prevention programmes focus on improving posture and rehabilitation from previous injuries rather than flexibility. It also suggests that injury can be predicted using musculoskeletal clinical defects and that this should be included in evaluation of players for predictive purposes.

Debedo *et al.* (2004) drew correlations between hamstring muscle stretching regimes implemented by professional football clubs and the occurrence of hamstring injuries

amongst the players. Thirty professional clubs in four divisions took part in the research during the 1998/1999 season. Flexibility protocols in clubs were variable and appeared to depend on staffing expertise. Hamstring stretching was the most important training factor associated with hamstring injury rates. Stepwise multiple regression analysis, using the specific training factors, was used to create a regression equation of hamstring strains. The use of standard stretching protocols, stretching technique and stretch hold time were proposed to be involved in a complex synergism which may reduce hamstring strains.

A random sample of 21 adolescent soccer teams aged 12 to 18 years was used by Emery, Meeuwisse and Hartmann (2005) to evaluate risk factors for injury in youth soccer players. Baseline measurements including a medical questionnaire; height measurement, weight measurement, leg dominance, dynamic balance, vertical jump test and a 20m shuttle run were done pre-season on all participating players. Injuries were then monitored during the following season along with exposure to match and training sessions. The findings suggested that having a previous injury in the past year increased the risk of injury in the current season. Left leg dominance also proved to leave players at an increased risk for injuries. There was no apparent increased risk associated with body mass index, dynamic balance, functional strength and endurance. The research design for the current research study is similar to this one by Emery *et al.* (2005) and includes balance, previous injury history and leg dominance as some of the factors being evaluated.

Earl, Hertel and Denegar (2005) aimed research at creating a prediction model to correctly predict patello-femoral pain in subjects. Sixteen subjects with, and 16

without patellofemoral pain were examined. An EMG (Electronic muscle activity measure) study, kinematic data during a step-down task and five static alignment assessments were performed. Based on these findings, a predictive function was created using static measures, joint angles and EMG activity as predictor variables to correctly predict patellofemoral pain. Static alignment discrimination was most predictive for patello-femoral pain. The static alignment tests included Hamstring flexibility, Iliotibial Band flexibility, pelvic tilt and navicular drop. These measures, bar the navicular drop, are all included in the biomechanical evaluation used in this study. It also shows that biomechanical variables can effectively be used in prediction functions to predict the occurrence of certain injuries.

Female collegiate athletes were also used in a research study by Devan, Pescatello, Fagghi and Anderson (2004) to examine whether Hamstring to Quadriceps strength ratios and structural abnormalities of the knee had any influence on knee overuse injuries. Fifty three subjects from women's field hockey, soccer and basketball teams volunteered for this research. Before the start of the sports season Hamstring to Quadriceps strength ratio were measured using a biodex system. Q-angle and genu recurvatum (Knee hyperextension) angles were also measured as well as Iliotibial band flexibility. Injuries were then monitored during the season. Ten overuse knee injuries were reported during the season in the group of participants. The athletes with decreased Hamstring:Quadriceps strength ratios and athletes with genu recurvatum incurred more overuse injuries than athletes without these abnormalities. Further research is suggested to identify further pre-season testing parameters which could be used to identify athletes at risk of injury.

Murphy, Connolly and Beynnon (2003) conducted a comprehensive literature review on risk factors for lower extremity injury. These factors were divided into intrinsic and extrinsic risk factors. Some of the extrinsic risk factors included level of competition; skill level; shoe type; ankle bracing and playing surface. Intrinsic risk factors examined included age; sex; phase of menstrual cycle; previous injury and inadequate rehabilitation; aerobic fitness; body size; limb dominance; flexibility; generalised joint laxity; ankle and knee joint laxity; muscle tightness; range of motion; muscle strength and imbalance; limb girth; postural stability; anatomical alignment and foot morphology. There is, however, little agreement with respect to the findings and further research is recommended to conclusively determine risk factors for lower extremity injury.

It can be seen from all the preceding research that there is grounds for injury prediction in sports participants and especially soccer players based on pre-season evaluation of a number of factors. Previous injury was identified along with leg dominance, postural problems and musculoskeletal deficiencies.

3.2.2 Prevention Programmes

A sub-aim of this research study is the creation of a preventative training programme based on the findings for the prevention of injuries amongst players identified by the prediction model. Current literature on preventative programmes will now be examined to evaluate the effectiveness on the prevention of injuries.

A neuromuscular preventative training programme was implemented by Mandelbaum, Silvers, Watanabe, Knarr, Thomas, Griffin, Kirkendall and Garret

(2005) to reduce Anterior Cruciate Ligament Injuries in female soccer players. A total of 1041 players were part of the intervention group and 1905 players served as control group in the 2000 season, with 844 players in the intervention group and 1913 players in the control group in the 2001 season. The players were all between the ages of 14 and 18 years. The intervention consisted of education, stretching, strengthening, plyometrics and sport-specific agility drills that replaced the traditional warm-up routine. In the 2000 season there was an 88% decrease in anterior cruciate ligament injuries in the intervention group and a 74% reduction in the intervention group of the 2001 season compared to the respective controls.

Research into the prevention of Anterior Cruciate Ligament injuries amongst female athletes was also conducted by Myer, Ford, Palumbo and Hewett (2005). Fifty-three female athletes aged between 13 and 17 years were used for this study. Their primary sports were identified as soccer, basketball and volleyball. An initial assessment was done of the participants that included vertical jump height testing, speed testing, single leg hop distance testing, strength testing and a computerised three dimensional biomechanical movement analysis. A six week pre-season training programme was then implemented focusing on plyometrics and movement; core strengthening and balance; resistance training and speed training. Forty one participants underwent the training programme and 12 athletes served as a control group which did not undergo any training. The trained athletes showed increase in strength, single leg hop distance, vertical jump height and also decrease valgus and varus torque at the knee joint during the dynamic movement analysis. The control group showed no significant changes during the 6 week training interval. This study shows that the combination of

multiple injury prevention training components into a comprehensive programme improves measures of performance and movement biomechanics.

Heidt, Sweeterman, Carlonas, Traub and Tekulve (2000) also implemented a preventative pre-season conditioning programme to evaluate its influence on the severity of injuries. Three-hundred female soccer players between the ages of 14 and 18 years were used for this research. Forty-two players participated in a seven week pre-season training programme consisting of sport specific cardiovascular conditioning, plyometric work, sport cord drills, strength training and flexibility exercises for the improvement of speed and agility. T-test evaluations revealed that the trained group had a statistically significant ($P=0.0085$) lower rate of injury when compared to the untrained group. The trained group also had a lower incidence of Anterior cruciate ligament injuries when compared to the untrained group (2.4% vs 3.1%). These results suggest that this type of conditioning has a significant influence on lowering the incidence of injuries in adolescent female soccer players.

The research by Myer *et al.* (2005) and Heidt *et al.* (2000) supports a comprehensive pre-season training programme for the prevention of injuries. It shows that training programmes addressing a number of training parameters could be effective in increasing performance and improving biomechanics, which would lead to decreased injuries.

A prospective intervention study was conducted by Junge, Rösch, Peterson, Graf-Baumann and Dvorak (2002) amongst youth amateur soccer players to determine its effectiveness at reducing injuries. The prevention programme included improvement

of warm-ups; regular cool-downs; taping of unstable ankles; adequate rehabilitation; promotion of the spirit of fair play; exercise to promote stability of the ankle and knee, exercises promoting flexibility of strength of the trunk and hip muscles as well as exercises to improve co-ordination, reaction time and endurance. Each player was also informed of their respective baseline testing and was instructed on how to improve individual weaknesses. The injury incidence per 1000 playing hours was 6.7 for the intervention group and 8.5 for the control group, proving that this intervention was successful in reducing injuries amongst youth players. The program also proved to have a larger effect in low skill than in high skill groups.

Proske, Morgan, Brockett and Percival (2004) used optimal angle of hamstring torque measured on nine previously injured and 18 uninjured athletes. The difference in optimal torque angle between previously injured and uninjured athletes suggested that previously injured athletes were more prone to eccentric damage and thus more injured to strain injuries than uninjured athletes. It was found that muscles showed less damage after repeated bouts of eccentric exercise, suggesting an adaptation process which protects it from further damage. It is suggested that athletes at risk of hamstring injuries, as measured by peak torque angle, be put on an eccentric training regime. There was also evidence that athletes that followed an eccentric training programme showed a significant reduction in the incidence of hamstring strains.

Other preventative studies will also be mentioned later in the chapter where literature on the individual test parameters included in this study is discussed. It can be seen from the discussed literature that there were a number of predictive studies done on

sports injuries. None of these previous studies used the test battery combined in this research, but some do contain elements from it.

3.3 INFLUENCE OF CERTAIN PARAMETERS ON INJURIES

The tests included in the literature review for possible inclusion in the test battery for this research are: an isometric quadriceps to hamstring ratio testing, EMG testing of the Vastis Medialis Oblique to Vastis Lateralis muscle strength ratio, a biomechanical evaluation, plyometric strength testing and proprioception and balance testing. The reasons for the inclusion and exclusion of these specific tests will now be discussed, based on available literature. The biomechanical evaluation includes a number of test parameters which will be evaluated including, but not limited to, foot arch position, pelvic symmetry, leg length discrepancies, saggital view of the lumbar area, thoracic rotation and different muscle length tests. A complete description of all the tests is given in chapter 4.

3.3.1 Isometric Muscle Strength of Quadriceps and Hamstrings

There have been many studies on the influence of hamstring and quadriceps muscle strength and the ratio of muscle strength between these two muscle groups on the occurrence of injuries. The testing of the hamstring to quadriceps ratios and the strength of hamstrings and quadriceps muscles in terms of torque and torque to body weight were considered for inclusion in the test battery. Rahnama, Lees and Bambaecichi (2005) encourage the assessment of muscle function as it can be used to reveal specific deficiencies in apparently healthy players which may predispose them to injury. Petersen and Hölmich (2005) also recommend that controlled studies should

be carried out with enough players to further examine the potential association between muscle strength and hamstring muscle strain injuries.

Askeling, Karlsson and Thorstensson (2003) conducted research to examine hamstring injuries in elite soccer players after pre-season strength training. Thirty players from two of the best premier league division teams in Sweden were divided into two groups. One group received specific hamstring training in the pre-season and the other group did not. Isokinetic hamstring strength and running speed were tested in both groups before and after the training period. Hamstring injuries were registered during the ten month observational period. The results confirmed that players in the training group showed lower incidence of hamstring injuries during the season. The training group also presented with significant increases in muscle strength and speed.

Agre and Baxter (1987) designed a study to determine whether deficits in lower extremity flexibility and muscle strength and asymmetry between left and right sides would affect susceptibility to hamstring or groin muscle strain injuries. Twenty five collegiate soccer players were used for the research and testing was conducted over a two season period. During these two seasons over which this study spanned, no hamstring or groin injuries were recorded in the player group. The lack of hamstring and groin injuries were ascribed to the initiation of a controlled warm-up and stretching programme, showing the importance of these factors on injury prevention.

During research conducted by Cameron, Adams and Maher (2003), it was found that an imbalance of thigh muscle strength was predictive of hamstring injury. Twenty elite players from a professional Australian Rules Football club were used for this

research. Pre-season strength measurements were conducted using a Cybex II isokinetic dynamometer. Movement extent discrimination testing was also done, using a purpose built device that tested neuromuscular control. Players were then monitored during the following season for hamstring injuries. Injured subjects had a significantly lower hamstring to quadriceps strength ratio and significantly greater quadriceps strength adjusted for their body weight than uninjured subjects. Hamstring to quadriceps ratios and quadriceps strength were shown to be significant predictors of hamstring injury. Movement extent discrimination was also shown to have predictive abilities for hamstring injuries.

In a comparison of factors that influence anterior cruciate ligament injuries in male and female athletes and non-athletes, Bowerman, Smith, Carlson and King (2006) found that there was very little difference in knee joint laxity between male and female participants in the study. It was, however, found that non-athletes had significantly more knee laxity than athletes. Athletes tested stronger than non-athletes in muscle strength testing, and males tested stronger than females. This research suggests that the well recorded higher incidence of Anterior Cruciate Ligament injuries amongst females cannot be attributed to higher laxity, but could be influenced by the weaker peak torque figures recorded in females. It is suggested that females are proportionately weaker than males in both quadriceps and hamstrings, leading to a similar hamstring to quadriceps ratio as males. This study recommends that there should be focused on improving hamstring to quadriceps ratios to reduce the risk of injury to both males and females.

Croisier and Crielaard (2000) conducted research to determine the isokinetic profile of specialised athletes with previous hamstring tears and recurrent complaints upon return to sports activities. Twenty three top athletes from professional soccer clubs, track and field events and martial arts were participants in this study. It was demonstrated that there was a frequent presence of muscle strength performance disorders amongst the subjects using isokinetic dynamometry. The reduction of peak torque was particularly evident during eccentric exertions. It is argued that persistent muscle strength abnormalities are a causative factor that gives rise to recurrent injuries.

In contrast, Bennell, Wajswelner, Lew, Schall-Riaucour, Leslie, Plant and Cirone (1998) showed that isokinetic strength testing of hamstrings and quadriceps could not be used to predict hamstring injuries in Australian Rules Football players. One hundred and two senior Aussie rules footballers were used for this study. Pre-season hamstring and quadriceps strength testing was done using a Kin-Com isokinetic testing device. Eleven players sustained Hamstring injuries during the season. There were no significant differences for any of the isokinetic test variables comparing the injured and uninjured legs of the players with unilateral Hamstring strains. Neither the injured nor uninjured legs of the players differed from the norms of test values for all players tested. A hamstring to opposing hamstring ratio of less than 0.90 and a Hamstring to Quadriceps ratio of less than 0.60 were not associated with increased risk of injury either.

Further research by Dauty, Potiron-Josse and Rochcongar (2003) also argues that hamstring to quadriceps ratio of less than 0.6 and other isokinetic parameters could

not be used to predict hamstring injury or re-injury in research conducted on 28 elite soccer players. Eleven players who sustained injury in the past 2 years were compared to 18 uninjured players. This study showed that an eccentric hamstring-to-concentric quadriceps lower than 0.6 represented the best indicator of previous hamstring injury. This ratio did not show any injury predictive properties, though.

It can be seen from these sources that there are conflicting findings as to whether Hamstring and Quadriceps strength and strength ratios between the knee flexor and extensor muscle groups have been shown to have an influence on upper leg injuries in sportspeople in a variety of sporting codes and settings. A second factor that needs to be considered during inclusion of tests in a test battery for youth soccer players in the South African milieu, is the costs involved and the lack of available funds in youth soccer structures. Based on the conflicting literature and the exorbitant costs involved in the test equipment and test procedures for isometric muscle testing (cybex machines cost more than R500 000, or alternatively testing at a recognised institution costs more than R500 per player), isokinetic muscle testing was excluded from the test battery.

3.2.5 Strength ratios of Vastus Medialis Obliquus to Vastus Lateralis

Many studies have shown that patellar dysfunction can lead to anterior knee pain. This patella dysfunction is often attributed to an incorrect Vastus Medialis Obliquus to Vastus Lateralis muscle strength ratio (Ng, Zhang & Li, 2006; Callaghan, McCarthy & Oldham, 2001; Powers, 2000; Souza & Gross, 1991).

Farahmand, Tahmasbi and Amis (2004) conducted research on patellar stability in cadavers and the influence of the different parts of the quadriceps muscle and the medial retinaculum on this stability. This was done by surgically severing different structures attached to the patella while adding lateral stress and then noting stability. It was found that the medial retinaculum is responsible for patellar stability only when the knee was fully extended. The Vastus Medialis and Vastus Lateralis were responsible for patella stability all through the range of knee motion. Vastus medialis dysfunction led to minimum patellar lateral stability at 30° of knee flexion. Most patellar dysfunction, like dislocation and subluxation, are reported to occur at 30° and this supports the hypothesis that these disorders are linked to Vastus Medialis dysfunction.

Sakai, Luo, Rand and An (2000) also conducted in-vitro cadaver studies on the influence of Vastus Medialis Oblique muscle on lateral patellar tracking. This study showed that the weakening of the Vastus Medialis Oblique muscle caused a lateral patellar shift at 0° and 15° of knee flexion and this was significantly different from normal. Research by Fox (1975) is used as source by Sakai *et al.* (2000) as stating that the the Vastus Medialis is the last muscle of the quadriceps to develop phylogenetically and it is the first to undergo disuse atrophy and the last to be rehabilitated after injury or surgery. Weakness of the Vastus Medialis was also related to lateral patellar instability in families where the Vastus Medialis developed poorly compared to the other quadriceps muscles.

Ng *et al.* (2006) examined the influence of biofeedback training on the EMG activity of Vastus Medialis and Vastus Lateralis muscles in subjects with patellofemoral pain

syndrome. They state that patellofemoral pain syndrome is usually due to weakness of Vastus Medialis Obliquus muscles resulting in abnormal patellar tracking. It was found that subjects had a significant improvement in patellar tracking and an 8% decrease in pain after the exercise training and resulting increase of VMO function.

In a study conducted by Callaghan *et al.* (2001), ten participants with patellofemoral pain and ten normal subjects were used to examine the influence of patellofemoral pain on the fatigue characteristics of the quadriceps muscles. This study showed a difference between the VMO:VL fatigue ratios between healthy subjects and subjects with patellofemoral pain syndrome. The ratio for fatigue of the VMO:VL was higher in participants with patellofemoral pain, indicating decreased VMO endurance in participants with patellofemoral pain. There was no statistical significance due to the small sample size.

Souza and Gross (1991) used 16 subjects for EMG testing of Vastus Medialis: Vastus Lateralis ratios. The subjects were divided into three groups. The subjects in group one was not suffering from any knee pain. In group two, the painful knee of subjects with unilateral anterior knee pain was tested and in group three the non-painful knee of the same subjects in group two were tested. The results of this study suggest that individuals with patellofemoral pain may differ from health individuals with regard to VMO: VL muscle activation patterns. This factor could interact with biomechanical factors in explaining the causes of patellofemoral pain syndrome.

A study was done to determine the influence of vastus muscle activity as measured by EMG on patellar tracking patterns in subjects with and without patellofemoral pain.

The study was conducted by Powers (2000), using 23 women with patellofemoral pain and 12 women without patellofemoral pain. When VL: VMO ratios were averaged over all angles of knee flexion the ratio was higher for participants with patellofemoral pain than for participants without patellofemoral pain. It was also found that there was more pronounced EMG activity measured in the VMO at end of range extension, indicating more involvement of the VMO at terminal knee extension. There was, however, no correlation between Vastus Medialis EMG activity and lateral patellar tilt in this study. The author suggests that this finding that VMO activity could not be shown to be predictive of patellar kinematics illustrates the limitations associated with the use of EMG ratios as indicators of patellofemoral joint pathomechanics.

Powers, Landel and Perry (1996) conducted research to determine differences in intensity and timing of muscle activity between Vastus medialis and Vastus Lateralis muscles as contributing factors to Patellofemoral pain syndrome. Forty five females ranging between 14 and 46 years were used for this research, 26 having patellofemoral pain and 19 without any knee pain. The patients were monitored with EMG electrodes in the Vastus Medialis, Vastus Lateralis and Vastus Intermedius muscles while walking and climbing stairs. During this study, no differences in onset or cessation of muscle activity was found among the Vastus muscles. Subjects with patellofemoral pain exhibited less activity of all vastus muscles for level and ramp walking. These results dispel the hypothesis that timing and intensity differences between the Vastus medialis and Vastus lateralis muscles are associated with patellofemoral pain.

Wong and Ng (2006) did research to examine the EMG activities of the medial and lateral vastus muscles with four different surface electrode placements during isometric knee extension. Eight non athletic male volunteers were used for this research. It was concluded that the position of surface electrodes had significantly affected the EMG readings of the vastus muscles. These findings have vital clinical implications for the application of EMG measurements of the vastus muscles, and the validity of recorded readings.

There is evidence suggesting that a disproportionate VMO: VL ratio could lead to anterior knee pain and patellar dislocation or subluxation. There is, however, also conflicting evidence that it does not have any effect and pathomechanics of the patella. Combined with the expert skill needed in correct placement of the electrodes, which could lead to incorrect measurements if not done, and the costs involved in obtaining the EMG testing apparatus, EMG testing was deemed inappropriate for the current research setting, and will not be included in the test battery.

3.3.3 Biomechanics

The term 'Biomechanics' refers to the evaluation of movement occurring in different sporting techniques. Correct biomechanics provides efficient movement and is likely to reduce injury risk. Abnormal biomechanics should be considered as a potential cause of non traumatic sports injuries. Faulty biomechanics may result from static (anatomical) abnormalities or functional (secondary) abnormalities (Brukner & Kahn, 2001). In this research study, the focus will be on static (anatomical) biomechanics and the parameters involved in this will be discussed.

Woo, Thomas & Chan Saw (2004) recognise biomechanics as a field with a very long history. It was described in Chinese and Greek literature as early as 400 – 500 BC. During the period of 1500 to 1700 the foundation of biomechanics was laid by famous contributors such as Da Vinci, Galileo, Borelli, Hooke and Newton. During the 1940's and 1950's pioneering work of musculoskeletal biomechanics was performed by legends such as Edward Muybridge, Arthur Steindler, Verne T. Inman, Henry R. Lissner and A.H Hirsch. Al Burstein and colleagues began to teach biomechanical principles to orthopaedic surgeons in the 1960's. Since then, the field of orthopaedic biomechanics has grown significantly and works have been published on biomechanics of bone, articular cartilage, soft tissues, upper extremities, spine and more. Neely (1998) reflects that there is a significant risk of injury when undertaking physical activities. Abnormal biomechanics of the lower limb has been implicated as a causative factor for injury.

Various studies on biomechanics have also shown that biomechanical abnormalities could lead to injuries. These studies will be discussed in this chapter and include amongst others: Rolls and George (2004); Witvrouw, Mahieu, Danneels and McNair (2004); Debedo, White and George (2004); Maganaris, Natrici, Almekinders and Maffulli (2004); Witvrouw, Danneels, Asselman, D'Have and Cambier (2003); Ribeiro *et al.* (2003); Suter, McMorland, Hertzog and Bray (1999); Neely (1998); Christensen (1997) and DonTigny (1990).

DonTigny (1990) examined the influence of anterior dysfunction of the Sacro-iliac joint on the etiology of lower back pain. His research shows that Sacro-iliac Joint dysfunction has a major influence on the occurrence of lower back pain. He also

quotes Cibulka, Rose, Delitto and Sinacore (1986) in stating that a sacro-iliac joint dysfunction could also contribute to Hamstring strains. Cibulka *et al.* (1986) did research on 20 patients with hamstring strains, where half of the patients were also treated with manipulation of the sacroiliac joint and subsequently showed greater improvement in hamstring torque than the control group. DonTigny (1990) used a comprehensive literature review to source his research.

This influence of the lumbo-pelvic area on Hamstring injuries is also confirmed by the research of Wallden and Walters (2005) that found a significant correlation between lumbo pelvic dysfunction and hamstring injuries in professional soccer players, particularly in players with recurrent Hamstring strains. Twenty professional male soccer players from five clubs with and without hamstring strains were evaluated during this research study. Manual assessment revealed higher levels of lumbo-pelvic dysfunction in players with injuries than in those without injuries.

In a case study conducted on a pole-jumper with a chronic Achilles tendinosis, Voorn (1998) attributed the cause of the injury to a sacro-iliac joint dysfunction. Local treatment of the injury failed to rectify the problem during treatment over the previous two seasons, and surgery was even considered. With further evaluation of the complete kinetic chain, the patient presented with a sacro-iliac dysfunction. This sacro-iliac dysfunction led to changes in the kinematic chain, including excessive external rotation of the one hip during movement. These changes in the kinematic chain continuates micro-trauma in the Achilles tendon, causing the persistence of Achilles tendinosis. This confirms again that a biomechanical abnormality in one body area can cause overuse injuries in other areas of the body.

Cibulka and Threlkeld-Watkins (2005) also showed that asymmetrical external rotation of the hip had a definite influence on the occurrence of patellofemoral pain. This case study was conducted on a 15 year old girl with eight months history of anterior knee pain. The patient presented with excessive external rotation of the right hip and also diminished medial rotation. According to Voorn (1998) this external hip rotation can be attributed to sacro-iliac joint dysfunction, and should be correctable with sacro-iliac re-alignment.

This is further supported by Suter *et al.* (1999) who showed in clinical evaluation that anterior knee pain is typically associated with sacro-iliac joint disfunction or malalignment. This may contribute to muscle inhibition, leading to anterior knee pain. After corrective manipulation of the Sacro-iliac joint, increased knee extensor torque and muscle activation were observed, leading to decreases in anterior knee pain. Eighteen patients were used during this research and EMG and Cybex testing was used to observe the peak torque produced and the neuromuscular firing of the Vastus Medialis muscle before and after the corrective manipulation.

There is thus a copious quantity of evidence that strongly suggests that the lumbo-pelvic complex and correct alignment of the sacro-iliac joint has a definite effect on the occurrence of lower limb injuries, and an evaluation of this joint complex should be included in any evaluations aimed at reducing sports injuries.

Maganaris *et al.* (2004) mentions a number of intrinsic factors that could lead to overuse tendinopathies. These factors, such as the status of the muscles, ligaments and bones around the tendon might alter the levels of tendon load, leading to overuse

injuries. Lack of flexibility and muscle imbalances are also frequently mentioned in the aetiology of tendinopathies. Limb alignment and body habitus are two more factors mentioned as causes of these injuries. All these intrinsic factors could be collectively referred to as biomechanical factors. A comprehensive literature review was used for data collection in this research and shows that biomechanical abnormalities can lead to overuse tendinopathies.

Gross (1995) argue that skeletal mal-alignments in the lower quarter may be the primary cause of musculoskeletal patient problems. Skeletal mal-alignments are also thought to sustain the presence of musculoskeletal problems that has some other causal mechanism. A literature review was done to substantiate this claim. Gross urges that clinicians should understand normal lower quarter biomechanics and compensations for skeletal mal-alignment. Joint mal-alignment was also said to be attributable to muscle strength imbalances or to relatively taut or lax ligaments, joint capsule or muscle tendon structures.

A comprehensive literature review conducted by Neely (1998) suggests that several biomechanical abnormalities may be significant risk factors for exercise related lower limb injuries. These are: limitation of range of ankle dorsiflexion, limitation of range of hip eversion, excessive joint laxity, leg length discrepancy, an excessively pronated or supinated foot, excessively high or low arches of the foot and a large Q-angle. Neely also states that there is lacking evidence that abnormal ranges of ankle plantar flexion, genu varum (bow legs) or genu valgum (knock knees) or undue muscle tightness may be potential risk factors for injury and that further research is needed in

these areas. Further evaluation of risk factors is suggested to increase the amount of available literature.

Ribeiro *et al.* (2003) conducted research on 50 junior Brazilian Futsal (Indoor soccer) players ranging from nine to 16 years of age. The players were divided into two groups, those who had suffered futsal injuries and those who had not. It was observed that there was a higher number of athletes with some kind of postural change at the injury site than players with similar injuries without regional postural changes at the injury site. The research suggested that postural changes are related to increased risk of injuries. Once postural mal-alignment has caused extra overload and demands more effort from the joint, there would be an improper biomechanical functioning in the joint. This creates an unnecessary stress and increased stretching of soft tissues, decreasing muscular and ligamentous efficiency that maintains joint balance. A qualitative assessment revealed that patients with ankle sprains and any sort of knee injuries all had postural changes in the injured site (foot/ankle, knee and lumbar spine respectively).

This research by Neely (1998), Maganaris *et al.* (2004), Gross (1995) and Ribiero *et al.* (2003) all suggest strongly that postural alignment, muscle imbalance and muscle lengths as well as joint range of motion needs to be included in any evaluation that is done to evaluate sportsmen with the aim of reducing future injuries. According to Brukner and Kahn (2001) the ideal stance occurs when the joints of the lower limbs and feet are symmetrically aligned with the weight bearing line passing through the anterior superior iliac spine, the patella and the second metatarsal bone of the foot.

This stance is the ideal towards which soccer players should strive to reduce overuse injuries.

Many studies suggest that muscle length has an effect on the occurrence of muscle injuries in participants in sports. Witvrouw *et al.* (2003) examined 146 Male professional soccer players before the 1999/2000 Belgian soccer competition. None of the players had a history of previous injury of the lower extremities in the previous two years. The flexibility of hamstrings, quadriceps, calf muscles and adductor muscles were measured before the start of the season. Players with hamstring and quadriceps muscle injuries showed significant decreases in pre-season muscle length testing when compared to uninjured players. The authors concluded that preseason hamstring and quadriceps muscle flexibility testing can identify male soccer players at risk of developing hamstring and quadriceps muscle injuries. This contradicts statements by Neely (1998) saying that muscle length does not have an effect on hamstring injuries.

Research by Debedo *et al.* (2004) also contradicts the statement by Neely (1998), showing that a stretching regime leading to improved muscle flexibility, does indeed lead to reduced hamstring injuries in professional soccer players. The research showed that Hamstring stretching regimes was one of the most important training factors associated with Hamstring strain rate. The higher the rate of use of the standard stretching protocols, the lower the hamstring injury rate that was recorded.

Conflicting research was published by Rolls and George (2004), who conducted research on 111 footballers ranging between nine and 19 years in age. Hamstring

muscle length was assessed at the baseline and injuries were monitored during the following season. Older players were shown to have significantly decreased hamstring muscle length when compared to younger players. Similar to Neely (1998), the findings showed that hamstring injuries were not overtly related to decreased muscle length of hamstring muscles.

There are thus two opposing schools of thought with regards to the involvement of muscle length on muscle injuries: some authors feel that it does have an effect on the occurrence of injuries and some feel it doesn't.

Using a comprehensive literature review, Witvrouw *et al.* (2004) made the important conclusion that sports involving bouncing and jumping activities with high intensity stretch shortening cycles requires a more compliant muscle tendon unit. Stretching in such sports will have a positive effect on the reduction of muscle injuries by increasing compliance of the muscle tendon unit. These sports include soccer and football. Stretching can significantly increase the viscosity of the tendon, increasing compliance and reducing injuries. When the type of sport contains low intensity or limited stretch shortening cycles like swimming, jogging or cycling, where muscle work is directly transferred by the tendon to the joint unit, stretching may not be advantageous for injury prevention. This could explain the findings by Neely (1998) and Rolls and George (2004) concerning muscle length and injuries.

There is therefore supportive evidence that muscle lengths need to be evaluated during evaluation of soccer players, as soccer is a sport containing rapid stretch and shorting cycles and require a properly pliable muscle tendon unit. Research by

Witvouw *et al.* (2003) and Debedo *et al.* (2004) was conducted on soccer players and support this theory.

In a study examining differences in foot kinetics and kinematics between high arched and low arched feet in runners, Williams, McClay, Hamill and Buchanan (2001), found that low arched runners had increased rearfoot inversion excursion, eversion to tibial rotation ratio and rearfoot eversion velocity. High arched runners had an increased vertical loading rate, which leads to increased bone stress and bony injury. Twenty runners with high arches and 20 runners with low arches were used for this research into foot biomechanics. The findings of the research suggest that arch structure is associated with specific lower extremity kinematics and kinetics. These differences may subsequently lead to differences in injury patterns in high arched and low arched runners.

In research published by Christensen (1997), based on a literature review, it is suggested that musculoskeletal imbalance and breakdown in response to weak pedal foundation can occur anywhere along the kinetic chain. It is stated that foot dysfunction can lead to chronic knee, pelvic and spinal distortions and exacerbate existing clinical conditions. Excessive pronation due to structural or functional abnormalities is said to be responsible for more chronic postural problems than any other foot disorders.

Foot biomechanics should also thus be included in any evaluation aimed at reducing injuries in sportsmen and more specifically, soccer players. As soccer players place a

great amount of strain through their feet with cutting manoeuvres and kicking, it is important that their foot biomechanics are sound and any deficiencies be addressed.

In the South African sports milieu, Hattingh (2003) introduced a new approach to injury prevention involving a biomechanical evaluation of 331 elite adolescent rugby players aged between 17 and 20 years in the North West Province. Pre-season biomechanical, anthropometric, physical and motor evaluations were conducted on the players and injury monitoring clinics were held on a weekly basis. This evaluation by Hattingh (2003) evaluated tests in a number of regions and tests were compiled from number of sources. The foot and lower leg area tests included: Achilles tendon suppleness test, longitudinal foot arch status test, forefoot positional test, rear foot standing test, rear foot lying test, transverse arch comparison test, foot mobility test and toe positional test. Further lower limb tests evaluated the knee. Test for the knee included: modified Thomas test (Quadriceps component), Quadriceps angle test, patella tilt test, patella squint test, knee height and VMO VL comparison test. The hip area of the lower limb included tests of: modified Thomas test (ITB and Hip flexor components), Gluteus maximus mobility test, Adductor mobility test, External hip rotation mobility test, Internal hip rotation mobility test and previous injury occurrence

Further test included by Hattingh (2003) was of the lumbo-pelvic area. Tests for this area included: Pelvic girdle leg length discrepancy test, Pelvic girdle Anterior Superior Iliac Spina (ASIS) comparison test, Pelvic girdle Posterior Superior Iliac Spina (PSIS) comparison test, Pelvic rami positional test, Sacroiliac crest test, Bilateral pelvic positional test, Thoraco-lumbar fascia test, Sacral rhythm test,

Functional spinal extension mobility test, Functional spinal flexion mobility test, Spinal rotational mobility test, Spinal side-flexion mobility test, Coronal axis lumbar area and Sagittal axis lumbar area.

The last area of interest was neurodynamics. Hattingh (2003) included the following test in the evaluation of neurodynamics: Straight leg raise neurodynamic test, Prone knee bend neurodynamic test and a slump neurodynamic test.

During the research by Hattingh (2003), clinic attendance records reported a disturbingly high percentage of chronic overuse injuries, correlating with the biomechanical and postural findings, especially with the regression in dynamic mobility findings reported by the junior elite club players. It showed that the poor biomechanical and postural findings necessitated the introduction of an injury prevention programme. Regionally, lower limb, spinal and neuronal regions were identified as major shortcoming in the players. These phenomena affected prime mover function and positional stability and increased the risk and presentation of over-use injuries. The Hattingh (2003) evaluation also contained testing of the shoulder girdle, thoracic and cervical spine, which is not included in this research study as very few injuries occur in those regions in soccer players.

Erasmus (2006) evaluated the effectiveness of an injury prevention programme based on this biomechanical evaluation compiled by Hattingh (2003). The research was conducted over a two year period using 15- and 16- year old schoolboy rugby players from two schools in the North West Province. Sixty players in total took part in this research study. Players were tested three times a year over the two year period- pre-

season, mid-season and at the end of the season. The influence of the prevention programme on test results of anthropometric, physical and motor and biomechanical and postural variables was recorded. Rugby injuries were screened and injury data collected through the use of weekly sports clinics. This research showed that a preventative programme had a positive effect on the reduction of intrinsic injuries in schoolboy rugby players and also significantly improved biomechanical and postural variables that were tested.

Steenkamp (2006) conducted research on 77 elite under 19 rugby players from the North West University PUK Rugby Institute. The players underwent pre-season motor, physical, anthropometric and biomechanical testing. Injuries were monitored through the season at twice weekly sports injury clinics conducted by a team of medical experts, biokineticists and sports scientists. Statistics were kept on player positional injuries, anatomical regions affected, types of injury, grades of injury, when injury occurred and lastly, necessary referrals.

In this research by Steenkamp (2006) 184 injuries were reported during the 2006 season. When the tight five forward players were examined, the ankle (5.58%) and knee (4.56%) were the most commonly injured body parts. Backline players and loose forwards mainly injured the shoulder (4.40% and 5.87% respectively) and the knee (5.32% and 4.56% respectively). The halfbacks injured mainly the upper limb (4.38%) and the lower leg (3.34%).

When comparing these injuries occurred to the lower limb dynamics of the tight five forward players, Steenkamp (2006) observed that there was a tendency to injury,

since their knee region and ankle and foot region showed biomechanical testing values close to the non-ideal and therefore dynamically loaded with an increased risk of injuries. The loose forwards had more shoulder injuries than the backline players because of the poor positional and musculature status of the upper limb, but fewer injuries in the knee region because of better biomechanical test values and therefore increased postural alignment. The halfbacks (scrumhalf) had the worst upper limb score of all player-groups and when considering the biomechanical status, they also had the biggest anomalies, correlating well with them scoring the highest percentage of lower leg injuries. This research shows that a pre-season biomechanical evaluation could be used to determine injuries during the following season.

It has been shown in all the preceding literature that biomechanical considerations play a large role in the occurrence of sports injuries in a number of different anatomical areas. A comprehensive, yet simply administered, pre-season biomechanical evaluation such as that propagated by Hattingh (2003) could prove to be an invaluable tool in the creation of an injury prediction model for youth soccer players, which can be used for the creation of a preventative training programme.

This biomechanical evaluation compiled by Hattingh (2003) contains elements of evaluation of most of the suggested causes for overuse injuries amongst sportsmen. It is also easy to administer by a trained professional and requires minimal equipment. It is thus ideal for the South African youth soccer milieu with its limited resources and finances, and based on all of these reasons, it was selected as the biomechanical evaluation model to be used in this research study. It has also been proven effective in

evaluating and helping with prevention of injuries in subsequent studies by Erasmus (2006) and Steenkamp (2006). This model evaluates mobility, dynamic stability and neural mobility. Testing will focus on the lower limb, pelvic and lower back area, as research on epidemiology described in the previous chapter shows that the majority of soccer injuries among youth players occur in these areas.

3.3.4 Balance and Proprioception

In 1906, proprioception was classically defined as “the perception of the joint and body movement as well as the position of the body or body segments in space” by Sherrington (Shield, Madhavan, Cole, Brostad, Demeulenaere, Eggers & Otten, 2005).

According to Stillman (2002), the proprioceptive system has some functions which are sensory and others which are not. The sensory functions, collectively termed “proprioception”, involve awareness of the spatial and mechanical status of the musculoskeletal framework. They include the senses of position, movement and balance. Proprioceptive sensation is integral to develop motor control when learning new skills. The contribution of the proprioceptive system to motor control during learned skills, however, is largely mediated without sensation; as are the roles in reflex protection of joints against potentially harmful forces and protection of the body against falls (balance).

Balance is the process by which we control the body’s center of mass with respect to the base of support, whether it is stationary or moving. Balance could be defined in three ways: the ability to maintain a position, the ability to voluntarily move and the

ability to react to a perturbation. All three components of balance are important in the ability to maintain an upright posture. Static balance refers to an individual's ability to maintain a stable antigravity position while at rest by maintaining the center of mass within the available base of support. Dynamic balance involves automatic postural responses to the disruption of the center of mass position (Blackburn & Voight, 2001).

The ability of athletes to control the position of their center of gravity has received attention as a potential risk factor for lower extremity injury. Increased variation in postural stability is associated with an altered neuromuscular control strategy; increased intersegmental joint forces and corresponding increased forces developed about articular, ligamentous and muscular structures (Murphy *et al.*, 2003).

This section will examine literature regarding proprioception and balance and the influence that abnormalities in balance and proprioception has on lower limb injuries affecting the ankle and knee joints. These measures will be included in the test battery used for this study based on the amount of supporting literature that shows its influence on injuries. A number of research articles and other literature have shown that ankle proprioception and balance have a definite, measurable influence on ankle injuries (Verhagen, Van der Beek, Twisk, Bouter, Bahr, & Van Mechelen, 2004; Stasinopoulos, 2004; Baltaci & Kohl, 2003) as well as injuries to other areas of the lower limb (Baltaci & Kohl, 2003; Murphy *et al.*, 2003). This literature will be analysed to justify the inclusion of proprioceptive measurement in the test battery of this study.

Trojian and McKeag (2006) demonstrated a significant association between a positive single leg balance test and ankle sprains while doing pre-season testing of high school and collegiate athletes. Two hundred and thirty athletes in men's American Football, men's and women's soccer and women's volleyball took part in the study. Not taping the ankle in athletes with a positive single leg balance test imposed an increased risk of sprain during the season. They proposed that the single leg balance test is a reliable and valid pre-season test for predicting the occurrence of ankle sprains. The test also requires minimum equipment to administer, and is thus ideal for the South African youth soccer setup.

Earlier research by McGuine *et al.* (2000) also showed that a pre-season single limb postural sway test could be used to serve as a predictor of ankle injuries during the following season. Subjects for this study were basketball players from five High Schools in the 1997/1998 and 1998/1999 basketball seasons. There were 210 participants taking part in the study. Subjects who demonstrated poor pre-season balance had nearly seven times as many ankle sprains as subjects with good balance.

The single limb stance test was also used with good effect by Cimbiz and Bayazit (2004) to identify athletes with decreased functional stability, who proved to be at higher risk of sustaining injury. The research was conducted on 60 voluntary participants, half of who did not have any rehabilitation of sustained injuries and half serving as an uninjured control group. The study showed that unreported lower limb injuries impaired proprioception and sense of balance and may increase risk of re-injury by these athletes. This proven single limb stance test as described by Trojian

and McKeag (2006) will be used as part of the test battery of this research study for the creation of a prediction model.

In research conducted by Verhagen *et al.* (2004) on players of the second and third Dutch volleyball divisions, it was shown that an intervention group that was subjected to a proprioceptive balance board programme had a lower incidence of ankle injuries than the control group who did not do any extra balance exercises. This lower incidence was limited to participants with previous ankle injuries only. This shows the preventative potential of balance board programmes on ankle injuries and the possibility of predicting injuries by measuring a balance deficit. A total of 288 volleyball teams participated in this study. Verhagen, Bobbert, Inklaar, Van Kalken, Van der Beek, Bouter and Van Mechelen (2005) evaluated the same programme by testing whether it had any influence on postural sway in previously injured and non-injured students over a five and a half week period. No differences in the centre of pressure excursion test were observed in an intergroup comparison of the intervention and control groups in this study.

A comprehensive literature study was conducted by Baltaci and Kohl (2003), investigating the influence of proprioceptive and balance training on ankle and knee injuries. Three studies evaluated in this literature review demonstrated an improvement in balance following a six-week, eight-week and ten-week training protocol. Patients with previous injuries showed the greatest improvements. Ankle proprioceptive training appeared to have decreased functional instability in ankles and decreased the incidence of re-injury. An increased risk of ankle injury is associated with functional ankle instability. Balance and proprioceptive training was shown to

have a positive effect on postural sway and the risk of injury in both sports and everyday activities. It also advocated that ankle perturbation disk training should be used as exercise in sports rehabilitation clinics to help protect against ankle sprains and improve the rehabilitation rate and healing of ankle sprains.

Stasinopolous (2004) subjected 52 Greek volleyball players with previous ankle injuries to either a preventative taping protocol; technical training or a proprioceptive training programme to do a comparative study on the influence of these interventions on the reduction of ankle sprains. Proprioceptive training proved to be effective in decreasing further ankle sprains. Testing for decreased proprioception is thus an important pre-season measurement.

A small case study was done by Mattacola and Lloyd (1997) on three subjects with 1st degree ankle ligament injuries. These subjects took part in a six week training programme consisting of manual muscle strengthening and proprioceptive exercises. Dynamic balance was tested three times a week on a single plane balance board. The intervention did not produce clearly observable improvements in balance for all evaluation criteria of all the conditions. It was, however, apparent that the proprioception and strength programme did positively influence all three subjects' ability to dynamically balance on the balance board.

Powers, Buckley, Kaminski, Hubbardt and Ortiz (2004) used a group of 38 subjects with unilateral functional ankle instability to determine the effects on muscle fatigue and static balance after participants underwent six weeks of a combined strength and proprioception training. The obtained results reflected that strength training,

proprioception training and the combination of the two failed to have a positive effect on postural stability characteristics. Serfontein (2006) also used a single plane balance board for pre-season testing of 240 schoolboy rugby players to determine the influence of this on injuries through the season. The balance results as measured with the single plane balance board did not prove to be effective in predicting lower leg injuries during the following season.

Rozzi, Lephart, Sterner and Kuligowski (1999) designed a research study to determine the effect of a four-week balance training programme on single leg stance. Subjects with functionally unstable ankles as well as subjects with non-impaired ankles were included in the study population. Both the participant groups with unstable and non-impaired ankles demonstrated significant improvements in balance ability following the training protocol. Subjects conducted their balance training on a Biodex Stability Training System, training three times a week. This study on subjects with unstable and non-impaired ankles suggests that single-leg standing ability could prove to be an effective tool in measuring the lack of balance and proprioception and also the effectiveness of balance and proprioception training.

In Calgary, Canada, 127 students from ten high schools took part in a six-week wobble-board home training programme. The intervention group consisted of 66 students who performed daily wobble board exercises for six weeks. The exercises were then continued as a maintenance programme once a week for the following six months while self-reported injury data was also collected for the following six months. The control group was tested along with the intervention group, but performed no exercises. After six weeks, the intervention group showed

improvements in both static and dynamic balance while the control group did not show any improvements. There was an evident protective effect of the balance training programme for a period of over six months, reducing sports-related injuries amongst the intervention group participants (Emery, Cassidy, Klassen, Rosychuk & Rowe, 2005).

Malliou, Gioftsidou, Pafis, Beneka and Godolias (2004) investigated the effect of balance training on proprioception and on the occurrence of lower limb injuries. The participants of this study were 100 young soccer players from four different teams. Two teams were assigned to both the experimental and control groups. The experimental group followed a proprioceptive training programme twice a week. Balance tests were conducted on a biodex system before and after the competition and injuries were monitored through the season. The experimental group showed significant differences between pre-training and post-training test values. There was also an important difference between the experimental and control group regarding the incidence of injuries, with the control group having a far higher injury rate. This leads to the conclusion that poor proprioceptive testing could be used to identify players at risk of injury.

Based on this research, one can conclude that there is an abundance of literature supporting the theory that a decrease in proprioception and balance could indicate and increased risk of injuries in the ankle and knee. Research also shows that proprioceptive and balance training can help decrease injury occurrence, which is also linked to increased balance and proprioception in measurements. A single limb stance test as advocated by Trojjan and McKeag (2006) will be used in the test battery to test

proprioception for inclusion in the prediction model, based on its ease of administration and the minimal equipment needs of the test. This test has been proven to be a good predictor of ankle injuries on its own, without the need for further costly and complicated balance tests to be administered (McGuine *et al.*, 2000; Cimbiz & Bayazit, 2004).

3.3.5 Plyometric Strength

The term “Plyometrics” refers to exercises that enable a muscle to reach maximal strength in as short a time span as possible. Such exercises usually involve some form of jumping, but other modes of exercise exist. The elements “ply” and “metric” come from the Latin roots for “increase” and “measure” respectively. The combination thus means “measurable increase” (Allerheiligen, 1994: 319). The goal of plyometric training is to decrease the time required between a yielding eccentric muscle contraction and the initiation of an overcoming concentric contraction. Normal physiological movement rarely begins from a static starting position but is usually preceded by an eccentric pre-stretch that loads the muscle and prepares it for the ensuing concentric contraction. (Voight & Tippet, 1999). Generally, there is very little literary evidence to support any influence of plyometric strength on the occurrence of sports injuries. Most evidence is anecdotal and deal with rehabilitation of existing injuries and not in preventing or predicting injuries.

Sportsmen are thought to possess above average conscious appreciation of joint position and motion. Many sports activities subject the lower extremity to plyometric types of activities. Soccer is one such activity. These plyometric activities may be partially responsible for enhanced proprioception when considering the effects of

muscle contraction and chronic neural adaptations on proprioception. The sensitivity of muscle spindles, and thus proprioception, is heightened when muscles are voluntarily contracted. The preparatory muscle contractions needed for plyometric activities serve to protect the joint but also increase sensory feedback to the central nervous system. Long term adaptations that occur in Golgi-Tendon Organs and muscle spindles may also improve proprioception. This combined effect should be very beneficial during training and match situations because the player should be able to protect against joint positions where he is vulnerable to injury (Swanik & Swanik, 1999). Decreases in plyometric strength means decreases in this sensory feedback and joint protection and could predispose players to injury.

Moss (2002) postulates that adequate power is an essential component that is necessary for an injured sportsman to return to activity. The criteria that are used for return to play should go hand in hand with the criteria used to help prevent or predict injury. If a sportsman returns to play without adequate preparation for all the facets, he is being set up for poor performance and injury. Decreased plyometric power could thus be said to lead to poor performance and to increase a player's chance of injury on the field of play.

Plyometric exercise is said to train the neuromuscular system by training it to more readily accept increased strength loads. This goal will help to ensure the body is prepared to accept the stress that will be placed upon it during return to function (Voight & Tippet, 1999:161). Should the necessary plyometric strength not be present, increased strength loads could lead to injury.

One study that did show a definite correlation between plyometric strength and the occurrence of lower leg injuries was done by Serfontein (2006). Two hundred and forty schoolboy rugby players from two schools were tested for plyometric strength before the commencement of the 2006 rugby season. The plyometric testing formed part of a test battery that was used. Players were then monitored for injuries during the season. Statistical analysis was done of the injuries that were monitored. The research showed that a plyometric ratio of below 0.483 for (left leg jumping height/bilateral jumping height); a ratio of below 0.492 for (right leg jumping height/bilateral jumping height) and a ratio of below 1.012 for (left leg + right leg jumping height/bilateral jumping height) could predispose a player for a lower leg injury. Plyometric testing in this study was done using a timing mat, but any means of testing could be used using this ratio, as long as left and right leg testing and bilateral testing is undertaken using the same method for all tests. It was also suggested that limb dominance be taken into consideration for these ratios in future research. These ratios will be used as part of the testing battery for the prediction of soccer injuries.

Generally there is a limited amount of literature concerning the influence of plyometric strength on injuries and even less literature on the possible predictive abilities of plyometric strength testing. This study aims to enhance literature in this area, based on the fact that Serfontein (2006) presented findings that a plyometric ratio could be used in a schoolboy rugby setting to predict injury. This research will help to further investigate this ratio and determine whether it could also be used for injury prediction in youth soccer players.

3.4 SUMMARY

This chapter contained literature pertaining to current prediction models and preventative strategies. Out of existing models, the ability of predicting injury was determined and several key factors influencing injuries in different types of sport were identified. Measuring tests for these different factors were identified and a test battery was compiled based on all of the research contained in the chapter. Certain tests were also excluded from the battery and deemed inappropriate based on the literature review, highly skilled nature and excessive costs. The next chapter will contain a detailed lay-out of the empirical investigation.

CHAPTER 4

EMPIRICAL INVESTIGATION

- 4.1 INTRODUCTION**
- 4.2 STUDY POPULATION**
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CHAPTER 4

EMPIRICAL INVESTIGATION

4.1 INTRODUCTION

The prevention of injuries is of the highest importance to researchers in sports injuries and also one of the aims of medical professionals dealing with these injuries in sports participants. This study creates a prediction model for the prevention of soccer injuries, using test variables that are of a correctable nature. The aim of this chapter is to explain the different components involved in the empirical investigation and discussing the different processes of data collection. The study population, injury and exposure recording and statistical method will be discussed. The biomechanical evaluation, proprioceptive testing and plyometric tests contained in the test battery will also be discussed.

4.2 STUDY POPULATION

The study population of this research study consists of players from two high schools and the three youth teams from the development structures of a professional club. The U/16 and U/18 teams from Milner High School and St Conrad's College in Klerksdorp will be used, as well as youth players from Platinum Stars Development Academy U/17, U/18 and U/19 teams. Milner High school and St Conrad's have 15 players per team and Platinum Stars 22 players per team. The parents or legal guardians of all players signed an informed consent form (Annexure A) before players participated in the research.

4.3 TEST PROTOCOL

4.3.1 Test Battery

The test battery for this research study will contain a biomechanical evaluation, plyometric testing, proprioceptive and balance testing and a previous history of injury questionnaire. Chapter 3 gives a detailed explanation for the inclusion of these tests in the test battery. These specific tests are also easy to administer and require the minimum equipment. In the South African youth club system, there is generally a lack of funds and any testing to be conducted should not rely on any tests requiring expensive equipment or highly trained, specialised personnel. Based on this, it is thus prudent to exclude tests such as isometric muscle strength testing (Cybex or Biodex), EMG muscle ratio testing, computerised balance testing or postural X-Ray investigations.

4.3.1.1 Biomechanical Evaluation

The biomechanical evaluation will be done according to the protocol compiled by Hattingh (2003). This protocol was compiled from and based on a number of existing biomechanical tests, which were combined for research into youth rugby injuries, proving it an effective evaluation tool. The biomechanical evaluation form can be viewed in Annexure B. This study will implement this biomechanical evaluation by Hattingh (2003) in a different milieu, to determine whether it is also applicable to youth soccer in South Africa. It is aimed at expanding the biomechanical research by Hattingh (2003) to other sporting codes. The evaluation will be done shortly before the commencement of the competitive season at the club and the schools. This evaluation will be divided into five regions with a dysfunction score being given for each region.

4.3.1.1.1 Foot and Lower leg region

The first region is the foot and lower leg. The tests by Hattingh (2003) that were compiled for this area include: Achilles tendon suppleness test, longitudinal foot arch status test, forefoot positional test, rear foot standing test, rear foot lying test, transverse arch comparison test, foot mobility test and toe positional test. The foot area has a dysfunction score calculated out of 10, and also contains previous injury as a parameter.

Achilles tendon suppleness test

The achilles suppleness test is described by Hoppenfeld (1976) as well as Brukner and Kahn (2001).

Equipment requirements: One plinth and a long-arm goniometer.

Test procedure: The player was placed in the supine position on the plinth, with both legs straight and the heels just protruding over the edge. The evaluator placed the left hand on the posterior of the ankle, stabilising the subtalar joint and holding the calcaneus, while the right hand grabbed the ball of the foot, pushing the forefoot into a dorsiflexed position. Approximately 30 kg of pressure was then applied. The degrees of forced plantar flexion were measured on the lateral aspect of the ankle joint using the long-arm goniometer. Range of motion (ROM) was then graded from 1 to 3 (1 is a range of 20° or more, which is considered ideal; 2 is between 10° and 20°, considered non-ideal and 3 is less than 10°, considered highly unsatisfactory). The ankle thus had a possible dysfunction score of 1 or 2 depending on whether the grade given was 2 or 3.

Longitudinal foot arch status test

Hoppenfeld (1976) describe this test as follows:

Equipment requirements: None.

Test procedure: The player stands upright and relaxed, feet shoulder width apart, facing the evaluator. The longitudinal medial arch (plantar vault) is evaluated by inserting the index finger between the plantar surface of the foot and the supporting surface. The ease with which the finger is inserted was used to determine whether the arch is considered high, low or normal. A low arch would not permit the finger to enter, a normal arch would permit finger entry and a high arch would allow “play” between finger and foot arch. Foot arches were then classified according to two parameters namely high arched and low arched feet. (High arch was classified as: 1 if absent or 2 if present. Low arch was classified as 1 if absent or 2 if present). A normal foot would have a score of 1 for both high and low arch classifications, while a foot with low arch would score 1 for high arch and 2 for low arch. A foot with a high arch would score a 2 for high arch and 1 for low arch. The foot would thus have a dysfunction score of 1 if it had either a low or high arch, and a dysfunction score of 0 in case of a normal foot.

Forefoot positional test

Equipment requirements: One goniometer, one plinth and one skin pencil.

Test procedure: The player stands as for the longitudinal arch status test. The marker is then used to identify the lateral aspect of the talus neck. The Z axis was then identified and marked. A goniometer is placed on the marked area, the control arm on the Z axis and the second arm measured the degrees of forefoot valgus. Measurements are classified into two categories: 1 is 10°- 0° of deviation from Z

axis (ideal); and 2 is $> 10^\circ$ of deviation from Z axis (non-ideal) (Brukner & Kahn, 2001; Hoppenfeld, 1976). A score of 2 would give a dysfunction score of 1 for the test.

Rear foot standing test

Described by Brukner & Kahn (2001) as follows:

Equipment requirements: One Plinth, one goniometer, one skin pencil and a 30 cm bench.

Test procedure: The player was instructed to lie prone on the plinth with both feet just over the edge of the plinth. The mid-point of insertion of the Achilles tendon (TA) into the calcaneus is then marked using a skin pencil. With the finger and thumb of the one hand on either side of the calcaneus, the mid-position of the posterior margin of the calcaneal bone was marked. A line bisecting the calcaneal bone is then drawn by connecting these two marks. A third point is then marked on the mid-point of the proximal calf muscle bulk. Lastly, a fourth point is identified where the calf muscle bulk inserted into the Achilles tendon. A line is then drawn between these two points on the calf muscle, which represents the pulling direction of the calf muscle complex.

The player is then instructed to stand upright with feet shoulder width apart on the bench, facing away from evaluator. The angle between the two drawn lines is then measured using the goniometer. For the purposes of statistics, the measurements are then used to define the foot according to pronation or supination. For pronation a score of 1 is given for less than 9° angle (ideal) and a score of 2 for a larger than 9° angle (pronated foot). For supination, an angle 0° - 9° is considered ideal (score of 1)

and an angle of less than 0° is considered supinated (score of 2). A normal foot would thus score 1 on both supination and pronation and have a dysfunction score of 0, where a pronated or supinated foot would have a dysfunction score of 1.

Rear foot lying test

This test is also described in Brukner and Kahn (2001).

Equipment requirements: One plinth, one goniometer and one skin pencil.

Test procedure: The player is positioned and marked as for the rear foot standing test protocol. The evaluator is positioned at the end of the plinth, placing the one hand on either side of the talus, approaching from the plantar aspect of the foot. With the thumb placed on the plantar aspect of the fourth and fifth metatarsal heads, the foot is eased into dorsiflexion, whilst controlling the neutrality of the talocrural joint system with the index finger and thumb of the hand. This position is then held in neutral (0° dorsiflexion) and the rear foot status was measured with the goniometer. The measurements in rear foot lying are classified similarly to the rear foot standing test protocol and similar dysfunction scores are assigned.

Transverse arch comparison test

Equipment requirements: One plinth.

Test procedure: The player is positioned lying prone on the plinth as for the rear foot lying test protocol. The evaluator is seated at the end of the plinth and then inspects the transverse arch area. Transverse arch areas are classified into two categories: 1 is normal plantar aspect with slight transverse arch (ideal); and 2 is a callused plantar aspect with a flat transverse arch (non-ideal) (Hoppenfeld, 1976). A flat, callused arch would thus give a dysfunction score of 1.

Midfoot mobility test

Equipment requirements: One plinth.

Test procedure: The player and evaluator are placed as for the rear foot lying test protocol. The player's medial aspect of the foot is then first flexed maximally and then extended by the evaluator, using a pincer grip with the hand around the metatarsal base area. The amount of mobility was noted (Corrigan and Maitland, 1987). For statistical purposes, the mobility is categorised into hypermobility (1 is normal mobility with 2 hypermobility) and hypomobility (1 is normal mobility and 2 is a hypomobile foot). A foot with normal mobility would score 1 for both hyper- and hypomobility and a dysfunction score of 0. A hyper or hypomobile foot would get a dysfunction score of 1.

Toe positional test

Equipment requirements: None.

Test procedure: The player is positioned standing erect and relaxed with feet shoulder width apart, facing the evaluator. The toe position is evaluated and categorised: 1 is ideal position (no valgus, rotation or deviation); and 2 is non-ideal (valgus/rotation/deviation present) (Hoppenfeld, 1976). An abnormal toe position would give a dysfunction score of 1.

All the dysfunction scores of the foot and ankle area are added together and the total dysfunction score for this area is calculated out of 10. This score also contains a parameter for previous injury, where a score of 1 is given if no previous injury was recorded in the previous injury questionnaire or a score of 2 if previous injury was noted.

4.3.1.1.2 Knee Region

The second area of evaluation is the knee region. The following tests from the Hattingh (2003) test battery was compiled for this region: Modified Thomas test (Quadriceps component), Quadriceps angle test, patella tilt test, patella squint test, knee height and VMO:VL comparison test.

Modified Thomas test (Quadriceps component)

According to Petty (2006), the test is described as follows:

Required equipment: One plinth, one long arm goniometer and one skin pencil.

Test procedure: In the modified Thomas test, three lower limb mobility measurements are assessed in a functional combination test. The player is instructed to stand at the end of the plinth, with the posterior aspects of the thighs firmly against it. The right hip and knee are then flexed towards the chest and the ankle is gripped on the anterior aspect with fingers locking just above the malleoli. The player then lies back into the supine position with the right leg still locked in the hand grip with extended elbows. The left leg is relaxed and hanging over the edge of the plinth. While holding this position, the mobility of the hanging lower limb is measured.

Quadriceps mobility component: The midline of the knee joint is marked on the lateral aspect using the skin pencil. The long-arm goniometer is then placed on the marked area with the control arm positioned in the line of the femoral shaft and the other in line with the lower leg. The angle is then measured. Measurements are classified into three categories: 1 is $> 70^\circ$ (ideal); 2 is 50° - 70° (non-ideal); and 3 is $< 50^\circ$ (highly unsatisfactory). A dysfunction score of 1 or 2 is noted for a

measurement in category 2 or 3 respectively. A measurement of 1 gives a dysfunction score of 0.

Quadriceps angle test (Q-angle Test)

According to Herrington and Nestor (2004) and Smith, Davies, O'Driscoll and Donell (2008) the following tests consist of:

Equipment requirements: One plinth, one small goniometer, one skin pencil and tape measure.

Test procedure: The player lies relaxed, on plinth in supine position with both legs extended. The evaluator then uses the skin pencil and identifies the tibial tuberosity and the apex of the patella. The medial and lateral aspects of the patella base are then also identified and marked. The midpoint between these two landmarks are then measured and identified. The ASIS is palpated, identified and marked. After this, a straight line is then drawn from the ASIS through the superior patella mid-position extending downwards. A second line is then drawn from the tibial tuberosity through the apex of the patella upwards. The point at which these two lines cross indicated the Q-angle of the measured leg. A small goniometer is placed on the crossing lines and the angle between them is measured. Measurements are classified into two categories: 1 is $< 9^\circ$ (ideal); and 2 is $\geq 9^\circ$ (non-ideal). A maximum dysfunction score of 1 can be scored in this test.

Patella tilt test

Equipment requirements: One plinth.

Test procedure: The player lies in a relaxed supine position on the plinth with both legs extended. The evaluator is positioned laterally at the level of the left knee.

Step 1: Using an imaginary coronal axis through the anterior surface of the patella, the amount of surface deviation from this line is observed. With discrepancy, the patella is categorized as 1, (not tilted or ideal).

Step 2: In event of deviation, the evaluator places the thumb on the lateral aspect of the patella and gently glides it medially (<1 cm). Only with a limit in the range of this glide is the patella categorised as 2 (tilted or non-ideal) (Brukner & Kahn, 2001).

Patella squint test

Equipment requirements: One plinth, one skin pencil and one short arm goniometer.

Test procedure: The player is positioned as for the patella tilt test. The evaluator is positioned laterally at the level of the left knee. The apex of the patella is identified and marked using the skin pencil. The medial and lateral aspects of the patella base are then also identified and marked. The midpoint between these landmarks is identified. A line is drawn from the patella mid-position through the inferior pole of the patella. The amount of patella squint (rotation) in comparison with the mid-limb sagittal line is now measure using the goniometer. Measurements are classified into two categories: 1 is < 10° (ideal); and 2 is > 10° (non-ideal) (Brukner & Kahn (2001). A non ideal squint position would give a dysfunction score of 1.

Knee height

Equipment requirements: One Plinth

Test procedure: The player is instructed to lie prone on the plinth with the legs bent at the hips and knees and the feet flat on the plinth. In this position, the evaluator

examines the height of the knees from a lateral perspective, noting whether there is any difference between the height of the anterior aspects of the two patellas in this position, indicating a difference in lower leg length (Hoppenfeld, 1976). The difference is categorised as 1 (no difference in height) or 2 (difference in height). A difference in height would also give a dysfunction score of 1.

VMO and VL comparison test

Equipment requirements: One plinth.

Test procedure: The player is positioned supine on the plinth, with knees extended. The evaluator is positioned at knee level, facing the upper legs. The subject is then instructed to isometrically contract the quadriceps muscle and hold the contraction. The evaluator then compares the muscle bulk of Vastus Medialis to Vastus Lateralis muscle. The evaluation is then classified into two categories: 1 is if VMO has greater bulk than VL (ideal); and 2 is if VMO is visually atrophied compared to VL (non-ideal) (Hoppenfeld, 1976; Petty, 2006). A visible deficiency would give a dysfunction score of 1.

The dysfunction score for the knee region is calculated out of 8 and also contains a parameter for previous injuries, where a previous injury of the knee would give a dysfunction score of 1, to be added to the total, giving a potential dysfunction score of 8.

4.3.1.1.3 Hip Region

The third area for which tests from the Hattingh (2003) biomechanical evaluation are compiled, is the hip area. Tests for this area include: modified Thomas test (ITB and

Hip flexor components), Gluteus maximus mobility test, Adductor mobility test, External hip rotation mobility test and Internal hip rotation mobility test. The dysfunction score for hip area is calculated out of 13, with previous injury forming part of the parameters.

Modified Thomas test (ITB and Hip flexor components)

According to Petty (2006), the test is described as follows:

Required equipment: One plinth, one long arm goniometer and one skin pencil.

Test procedure: The same position as for the Modified Thomas test (quadriceps component) is assumed. The hip flexor and Iliotibial band (ITB) components are then assessed as follows:

Iliopsoas mobility: Lateral midline of the hip joint is palpated on the greater trochanter of the femur, identified and marked by the evaluator. The long lever goniometer is placed on this identified point, with one goniometer arm parallel to the horizontal and the second in line with the femoral shaft. The angle is then measured. This angle is then classified as follows: 1 is $> 30^\circ$ (ideal); 2 is 15° - 30° (non-ideal); and 3 is $< 15^\circ$ (highly unsatisfactory).

ITB mobility: The anterior aspect of the ankle joint is marked using the skin pencil. With the arm of the goniometer, the amount of deviation from the coronal mid-position is then measured (The amount of rotation or deviation from the midline of the sagittal mid-position). Measurements are then classified into three categories: 1 is neutral (ideal); 2 is 0° - 10° of deviation (non-ideal); and 3 is 10° - 30° of deviation (highly unsatisfactory).

With both of these tests a resulting test value of 2 or 3 would amount to a dysfunction score of 1 or 2 respectively.

Gluteus Maximus mobility test (short hip extensor mechanism mobility test):

According to Hattingh (2003) the following test consists of:

Required equipment: One plinth, one goniometer and one skin pencil.

Test procedure: The player is positioned supine on the plinth with extended legs. The evaluator is positioned at side of plinth facing the lower limbs. The knee closest to the examiner is flexed to 90° and the lateral aspect of the ankle rested on the opposite knee, dropping the thigh into external rotation. From this point the flexed knee (90°) and externally rotated hip are flexed upwards (the external rotation of the hip joint is maintained up to maximum hip flexion). With the lower limb position maintained at full hip flexion, the long-arm goniometer is used to measure ROM of hip flexion of the externally rotated hip. Measurements are then classified into three categories: 1 is > 120° (ideal); 2 is 90°-120° (non-ideal); and 3 is < 90° (highly unsatisfactory). A dysfunction score of 1 or 2 can be achieved in this test in the case of non-ideal or highly unsatisfactory result.

Adductor mobility test

According to Hoppenfeld (1976) the following test is described as follows:

Equipment requirements: One plinth and one long-arm goniometer.

Test procedure: The patient is placed supine on plinth with both knees extended. The evaluator is positioned at the side of the plinth facing the lower limbs. The opposite leg is abducted and the knee bent 90° and the lower leg hooked over the edge of the plinth. This stabilised the limb and controlled the rotation thereof. The

limb closest to the evaluator is then abducted, with hip rotation controlled in neutral. The movement is continued until the maximum range is reached. The goniometer is then placed on the umbilicus with the arms representing the femoral shaft positions. The angle is then measured and recorded. Measurements are classified into three categories: 1 is $> 120^\circ$ (ideal); 2 is 100° - 120° (non-ideal); and 3 is $<100^\circ$ (highly unsatisfactory). A dysfunction score of 1 or 2 could be scored during this test.

External hip rotation mobility test

According to Petty (2006) and Hoppenfeld (1976) the following test is described as follows:

Equipment requirements: One plinth, one long-arm goniometer and one skin pencil.

Test procedure: The player lies supine on the plinth. The evaluator then flexes both the hip and the knee to 90° and mark the apex of the patella on the flexed knee. The one hand stabilises the inferior portion of the thigh and the other holds on to the ankle, maximally externally rotating the hip joint. The goniometer is then placed on the identified area and the amount of rotation in comparison with the horizontal axis running through the ASIS's of the player, is measured. Measurements are classified into three categories: 1 is $> 90^\circ$ (ideal); 2 is 60° - 90° (non-ideal); and 3 is $< 60^\circ$ (highly unsatisfactory). The player could score a dysfunction score of 2 or 3 in this test.

Internal hip rotation mobility test

Equipment requirements: One plinth, one long-arm goniometer and one marker.

Test procedure: The player is positioned exactly as for the external rotational mobility test, except that the ROM is now tested by internally rotating the bent leg

(Petty, 2006; Hoppenfeld, 1976). Measurements are then taken and classified into three categories: 1 is $> 30^\circ$ (ideal); 2 is 15° - 30° (non-ideal); and 3 is $< 15^\circ$ (highly unsatisfactory). A dysfunction score of 2 or 3 could be recorded with this test.

The hip area has a maximum combined dysfunction score of 13 and this combined dysfunction score will be used for injury prediction purposes along with the individual scores obtained in the different tests. This score also includes a score of 1 or 0 for previous injuries to the area, with 1 indicating a previous injury and 0 no previous injury.

4.3.1.1.4 Lumbo-Pelvic Region

The fourth region is the Lumbo-pelvic area, which contains the following tests of the Hattingh (2003) evaluation: Pelvic girdle leg length discrepancy test, Pelvic girdle Anterior Superior Iliac Spina (ASIS) comparison test, Pelvic girdle Posterior Superior Iliac Spina (PSIS) comparison test, Pelvic rami positional test, Sacroiliac crest test, Bilateral pelvic positional test, Thoraco-lumbar fascia test, Sacral rhythm test, Functional spinal extension mobility test, Functional spinal flexion mobility test, Spinal rotational mobility test, Spinal side-flexion mobility test, Coronal axis lumbar area and Sagittal axis lumbar area. The dysfunction level for this area is calculated out of a score of 21.

Pelvic girdle leg length discrepancy test

According to Hoppenfeld (1976) the test is described as follows:

Equipment requirements: One plinth.

Test procedure: The player is positioned supine on the plinth with the heels just over the edge. The evaluator then ensures symmetrical positioning of the player on the plinth. Standing at end of the plinth at the player's feet, the evaluator places both thumbs firmly against the inferior aspect of the medial malleoli. The player's straight legs are lifted (30°), elongated and replaced. Differences in malleoli position and symmetry are then noted, recorded and categorised: 1 is medial malleoli height left equals right (ideal); 2 is < 1cm discrepancy (slightly displaced) (non-ideal); and 3 is > 1cm discrepancy (highly unsatisfactory). A dysfunction score of 2 or 3 could be scored in this test depending on the degree of length discrepancy.

Pelvic girdle Anterior Superior Iliac Spina (ASIS) comparison test

According to Hoppenfeld (1976) and Brukner and Kahn (2001) the test is described as follows:

Equipment requirements: One plinth and one skin pencil.

Test procedure: The player is positioned supine, as for the leg length discrepancy test. The player is then requested to expose the anterior superior iliac spine. This bony landmark is then carefully marked at the inferior border of both prominences. Symmetrical positioning of the player is ensured. The evaluator's thumbs are then placed on the marked areas and the level of symmetry is then noted. Status is categorised as follows: 1 is symmetrical (ideal); and 2 is asymmetrical (non-ideal). A dysfunction score of 1 could be scored during this test in case of asymmetry.

Pelvic girdle Posterior Superior Iliac Spina (PSIS) comparison test

According to Tong, Heyman, Lado and Isser (2006), Kmita and Lucas (2008), Kim, Ko, Rhee, Lim, Lee, Im and Lee (2007) and Fryer, McPherson and O'Keefe (2005) the following test consists of:

Equipment requirements: One plinth and one skin pencil.

Test procedure: The player is placed in the four-point kneeling position on the plinth. He is then ordered to sit back on his heels (with gluteal area touching) and while sustaining the position, flex forward until his head is on the plinth, placing the back in a flexed position. The evaluator carefully exposes, palpates, identifies and marks the inferior edge of the PSIS. The thumbs are now positioned on the marked areas and the symmetry assessed. Status is categorised as follows: 1 is symmetrical (ideal); and 2 is asymmetrical (non-ideal). A dysfunction score of 1 is possible in this test in case of asymmetry.

Pelvic rami positional test

According to Hoppenfeld (1976):

Equipment requirements: One plinth.

Test procedure: The player is positioned supine with the superior pubic area just exposed. The evaluator ensures symmetrical positioning of the player. From the ASIS the thumbs are then moved medially and obliquely until they are positioned on the pubic tubercles of the superior pelvic rami. The area is then assessed for asymmetry. The symmetry status is categorised as follows: 1 is symmetrical (ideal); and 2 is asymmetrical (non-ideal). A dysfunction score of 1 is possible in this test in case of asymmetry.

Sacroiliac cleft test

According to Hattingh (2003), the following test consists of:

Equipment requirements: One plinth.

Test procedure: The player is positioned as for the PSIS comparison test. The evaluator carefully exposes the sacro-iliac joint (SIJ) area. He then places his thumbs on the joint margin of the SIJ and assesses for cleft asymmetry. The symmetry status is then categorised as follows: 1 is symmetrical (ideal); and 2 is asymmetrical (non-ideal). A dysfunction score of 1 can be achieved with this test.

Bilateral pelvic positional test

Equipment requirements: Tape Measure, one skin pencil, stool

Test procedure: The player stands erect and relaxed with both the ASIS as well as the PSIS well exposed. The evaluator is positioned sitting next to the player facing the player's side. The inferior edge of both the ASIS and the PSIS are then carefully palpated, identified and marked with the skin pencil (Hoppenfeld, 1976). The height difference between the ASIS and PSIS is then measured and recorded. Measurements are categorised as follows: 1 is 2-3cm discrepancy (ideal); 2 is 3-5cm discrepancy (non-ideal); and 3 is > 5 cm discrepancy (highly unsatisfactory). A non-ideal or highly unsatisfactory result would give a dysfunction score of 1 or 2 respectively.

Thoraco-lumbar fascia test

According to Petty (2006) the following test consists of:

Equipment requirements: One plinth and tape measure.

Test procedure: The player is placed in a side-lying position with his head placed at the top end of plinth. The legs are then both bent at 90° angles at both hip and knee. The evaluator then aids the player first onto the elbow and then onto the hand which is placed at the edge of the plinth. It is ensured that the player is positioned in a straight line before the test procedure starts. The distance between the iliac crest and the surface of the plinth is then measured. Measurements are classified into three categories: 1 is $\leq 1\text{cm}$ (ideal); 2 is 1-3cm (non-ideal); and 3 is $>3\text{cm}$ (highly unsatisfactory). This test has a possible dysfunction score of 1 or 2, depending on a respective score of 2 or 3 in the measurement.

Sacral rhythm test

Equipment requirements: One plinth.

Test procedure: Player lies in prone position on the plinth with his head close to the top edge. Hands are positioned as for a push up underneath the shoulders. The evaluator, positioned on the side of the plinth, place both thumbs on the left and right Posterior Superior Iliac Spines (PSIS). The player now performs the push-up without lifting the hips. The evaluator assesses the symmetry of the extension movement in this region using thumb movement at the respective PSISs (Petty, 2006). The movement is categorised into the following: 1 is symmetrical movement (ideal); and 2 is asymmetrical movement (non-ideal). A maximum dysfunction score of 1 is possible in this area.

Functional spinal extension mobility test

According to Petty (2006) the test consists of:

Equipment required: One plinth.

Test procedure: The player is positioned lying prone, with the hands positioned underneath the shoulders. A push-up is performed with elbows locked in extension, with the player instructed to try and keep the hips on the plinth. The evaluator then measures the distance between the ASIS and the surface of the plinth. Measurements are categorised into the following: 1 is < 2cm (ideal); 2 is 2-3cm (non-ideal); and 3 is > 3 cm (highly unsatisfactory). A dysfunction score of 1 or 2 is possible with this test.

Functional spinal flexion mobility test

Hoppenfeld (1976) describes the test as follows:

Equipment requirements: None.

Test procedure: The player stands erect and relaxed, with feet shoulder width apart. While keeping the knees in an extended position, the player flexes forward and attempts to touch the ground with crossed hands. The player is instructed to flatten the palms on the floor, if possible. Flexion is then categorised into: 1 palms placed flat on the ground (ideal); 2 fingers touching ground (non-ideal); or 3 unable to touch ground (highly unsatisfactory). With inability to touch the ground with flat palms or with fingertips, a dysfunction score of 2 or 1 is respectively given with this test.

Spinal rotational mobility test

Petty (2006) describes the test as follows:

Equipment requirements: One plinth.

Test procedure: The player is seated in a stable, erect position on the plinth, with upper legs stabilised on the plinth and lower legs hanging over the edge of the

plinth. The arms are crossed, with hands on opposite shoulders. The evaluator is positioned behind the player and, placing his hands on the player's shoulders, rotates the trunk to the edge of its range. The degree of rotation as measured between the hips and shoulders is noted and categorised as follows: 1 is $\geq 90^\circ$ rotation (ideal); 2 is rotation at 70° - 90° (non-ideal); and 3 is $< 70^\circ$ rotation (highly unsatisfactory). The test is repeated to both sides. Decreased rotation will result in a dysfunction score of 1 or 2, depending on the lack of rotation.

Spinal side-flexion mobility test

According to Petty (2006), the following test consists of:

Equipment requirements: One plinth.

Test procedure: The player is positioned as for the spinal rotational mobility test, with both arms relaxed next to the sides and elbows bent 90 degrees. The evaluator stands behind the player and stabilises the pelvic girdle on the left and then laterally flexes the trunk to the opposite side. This flexion is performed to the end of its range without any rotation movement occurring. This procedure is also repeated to the other side. The side-flexion range is categorised as follows: 1 is easy elbow contact with plinth by the player without stretching sensation and resistance (ideal); 2 is elbow contact with stretching sensation and resistance (non-ideal); and 3 is unable to touch surface (highly unsatisfactory). A lack of sideflexion would result in a dysfunction score of 1 or 2 being awarded to the player.

Coronal axis lumbar area

According to Kendall, McCreary and Provance (1993) as well as Brukner and Kahn (2001) the following test consists of:

Equipment requirements: One high stool.

Test procedure: Player stands erect and relaxed, feet at shoulder width, with the examiner seated on a high stool facing the subject laterally. Using an imaginary coronal axial line passing through the midline of the subject, the postural position is evaluated. The lumbar area is then categorised as: 1 is ideal (within acceptable anatomical postural limits and normal lordosis); and 2 is non-ideal (Excessive or non-existent lordosis). A test result of 2, would give a dysfunction score of 1.

Sagittal axis lumbar area

Kendall, McCreary and Provance (1993) and Brukner and Kahn (2001) describe the test as follows:

Equipment requirements: One stool.

Test procedure: The player is positioned as for the coronal evaluation, with the examiner positioned posterior on the high stool. An imaginary sagittal axis passing through the midline of the subject is used, evaluating the postural position. The following lumbar region is categorised as follows: 1 is ideal (with acceptable anatomical postural limits close to sagittal axis); 2 is non-ideal (deviating from axis with a scoliosis). A score of 2 in this test would give a dysfunction score of 1.

In the lumbar area, a combined maximum dysfunction score of 21 can be scored, and will also be used for injury prediction purposes.

4.3.1.1.5 Neurodynamics

The last area of interest is neurodynamics. Tests compiled from the Hattingh (2003) evaluation for this area include: Straight leg raise neurodynamic test, Prone knee bend

neurodynamic test and a slump neurodynamic test. Dysfunction is calculated out of a score of 6 for this area. The total biomechanical dysfunction score is thus calculated out of 58.

Straight leg raise neurodynamic test

According to Butler (1991) and Petty (2006) the following test consists of:

Equipment requirements: One plinth and one long-arm goniometer.

Test procedure: The player is positioned supine on the plinth. The trunk and hips are in a relaxed, neutral position. The evaluator places one hand under the Achilles tendon and the other above the knee of the leg. The leg is then lifted from the plinth, with the hand above the knee preventing any knee flexion. The limb is lifted as a solid straight lever, moving from a fixed point in the greater trochanter of the hip joint. The limb is lifted up to the end of its range or until symptoms of discomfort are elicited. Using the goniometer (with the apex of the hip trochanter as midpoint) the ROM is noted and categorised as follows: 1 is $\geq 90^\circ$ (ideal); 2 is 70° - 90° (non-ideal); and 3 is $< 70^\circ$ (highly unsatisfactory). A dysfunction score of 1 or 2 could be achieved with this test.

Prone knee bend neurodynamic test

According to Butler (1991) and Petty (2006) the following test consists of:

Equipment requirements: One plinth.

Test procedure: The player is positioned prone on the plinth. The lower limb is then passively flexed at the knee, moving the calcaneus towards the gluteal area until end of ROM is reached or until symptoms of discomfort are elicited. This range of knee flexion is then noted. Players are classified into three categories: 1 is

heel touching gluteus area with little resistance (ideal); 2 is heel touching gluteus area with strong resistance (non-ideal); and 3 is heel not touching (highly unsatisfactory). A dysfunction score of 1 or 2 can be achieved during this test in cases of non-ideal or highly unsatisfactory results.

Slump neurodynamic test

According to Butler (1991), Maitland, Hengeveld, Banks and English (2001) and Petty (2006) the following test consists of:

Equipment requirements: One plinth.

Test procedure: The player is positioned seated on the plinth, well back with legs over the side of the plinth (popliteal area of the knee at the edge). Hands were interlocked in a relaxed position behind the back lower back. The player is then instructed to slump with cervical spine remaining in extension. The evaluator now applies overpressure to thoracic and lumbar spine from a superior direction. This position is maintained. Instruction is now given to flex the cervical spine, pressing the chin to chest, again with gentle overpressure from superior by the examiner. Maintaining this position, the player is now instructed to extend the knees, first the left, then the right. ROM and any discomfort are noted. With the knees in this extended position, dorsiflexion of the ankle and foot are carefully added. ROM and any discomfort are noted again. The test is then repeated on the opposite side. Discomfort and ROM are also noted on the opposite side. Players are classified into three categories: 1 is full range with dorsiflexion and asymptomatic (ideal); 2 is full range with dorsiflexion and discomfort (non-ideal) and 3 is limited range with tension (highly unsatisfactory). A dysfunction score of 1 or 2 is recorded for this test in case of a non-ideal or highly unsatisfactory result.

4.3.1.2 Balance and proprioception test

A single limb stance test will be used to evaluate balance and proprioception. This test was described by Trojian and McKeag (2006) and was proven to be effective as an individual test at predicting injury not only by them, but also by McGuine *et al.* (2000) and Cimbiz and Bayazit (2004). This test does not require any equipment and is ideal for the South African context, where funding is generally limited.

Equipment requirements: None.

Test procedure: The subject is instructed to stand barefoot on a single limb by lifting the second leg. The lifted limb is bent at the knee, and held slightly part from the leg being stood on. The arms are held next to the sides, slightly away from the body. The player is then instructed to obtain a balanced position without any movement of raised leg, arms or the foot being balanced on. After this balanced position is attained, the player is then instructed to close the eyes for a period of 10 seconds, which is measured using a stopwatch. Any movement of the arms in relation to the body, the bent leg in relation to the other leg or movement of the foot being balanced on is defined as a positive test and will indicated decreases in proprioception and balance. In the event of a limb testing positive, a second chance is given at balancing on this limb. Only the result of this second test is considered, so if the first test is positive and the second negative, the test result is considered negative. The test results are then recorded on the result form.

4.3.1.3 Plyometric testing

The wall mark plyometric test has been used in many studies as an effective measure of plyometric strength (Badenhorst, 1998; Hattingh, 2003; Erasmus, 2006, Steenkamp, 2006). The test requires minimal equipment, and is easy and cheap to

administer. There are other tests available, but they involve equipment such as sensory mats or handheld computers (Serfontein, 2006) which are expensive and not readily available.

Equipment requirements: Blue chalk powder, tape measure, smooth wall.

Test procedure: The procedure is described by Kirby (1991). The chalk powder was applied to the middle finger of the player. He was then instructed to stand next to the wall with the arm closest to the wall stretched out vertically above his head with his heels on the floor. A mark is then made on the wall. This is the first mark. With chalk applied to his finger, the player was instructed to crouch and then to jump maximally with both legs together. The player then jumped as high as possible and made a second mark on the wall. The player was allowed to use his arms during the jump. The distance between the first and second mark was recorded. The best of three attempts was recorded as the final height. The test was then repeated in the exactly same manner for the left and right leg respectively for a unilateral jump height to be measured. The unilateral heights were recorded on the results sheet as either the dominant or non dominant leg, for standardised comparison purposes.

The ratios of ND/Bil (Non dominant leg plyometrics/ Bilateral plyometrics), D/Bil (Dominant leg plyometrics/ Bilateral plyometrics) and ND+D/Bil (Non dominant leg + dominant leg plyometrics/ Bilateral plyometrics) will also be calculated. Serfontein (2006) showed that these ratios could be an important determinant for intrinsic lower leg injuries.

4.4 INJURY AND EXPOSURE RECORDING

Injuries will be monitored by a qualified Physiotherapist during the season and recorded on the prescribed injury recording form (Fuller, Ekstrand, Junge, Andersen, Bahr, Dvorak, Häggglund, McCrory & Meeuwisse, 2006) (Annexure C) for each of the involved teams. This injury report form was created for the standardisation of soccer epidemiological research. The form contains information on the site of injury (Head/Face, Neck, Shoulder, Upper Arm, Elbow, Lower Arm, Wrist, Hand/Finger/Thumb, Sternum/Ribs/Upper Back, Lower Back/Pelvis/Sacrum, Hip/Groin, Thigh, Knee, Lower leg/TA, Ankle, Foot/Toe or Other); severity of injury in days missed (Zero Day, Slight (1-3), Minor (4-7), Mild (7-14), Moderate (14-28), Major (28+)); mechanism of injury (contact or non-contact); type of injury (Sprain, Strain, Contusion, Fracture, Dislocation, Overuse or Other) and whether it was a match or training injury. It also contains information on what type of contact caused the injury and also when in a match the injury occurred. Coaching staff will keep track of exposure to training activities and match play after receiving proper instruction on the procedure. These training and match hours will be used along with the recorded injuries for creating an epidemiological profile. Injuries will be expressed as the amount of injuries per 1000 play hours.

The players are not subjected to specific training programmes during the season by the researcher, as the aim of the research is to investigate the influence of the pre-season testing on injuries during the season without any interference in the normal training regime of the coaches. The testing was conducted at the end of the pre-season, thus testing players after they had finished their normal pre-season training programme conducted by the coach. This gave a good indication of the influence of

the coach's training on the physical profiles of the players. Interventions would be done in future seasons during the pre-season training based on testing before the pre-season training and the results of this research study.

4.5 STATISTICAL METHOD

Statistical analysis will be done of the test battery variables and the recorded injuries using logistical regression (STATSOFT, Inc., 2003). This function is used to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable. In this study, these independent variables are the results of the plyometric, proprioceptive and biomechanical testing. These variables will be used to predict the inclusion of a player in the injured group. A linear equation of the type $\text{GROUP} = a + b_1 * x_1 + b_2 * x_2 + \dots + b_m * x_m$ fits this model. In this equation a is a constant and b_1 through b_m are regression coefficients. Those variables with the largest regression coefficients are the ones that contribute most to the prediction of group membership (STATSOFT, Inc., 2004). A linear equation of this nature will be created to predict the risk of non contact soccer injuries to youth players. During the statistical equation the results from players with ankle injuries, lower leg injuries, knee injuries, upper leg injuries and lower back injuries will be also be compared to the rest of the group to determine key differences between the groups of injured vs uninjured players that could be used to predict group membership and to determine whether classification functions could also be created for specific anatomical areas. The Hosmer and Lemeshow inferential goodness-to-fit test (Hosmer and Lemeshow, 2000) will be used on the model to evaluate validity. A cross-validation method will also be used to re-allocate the test results for all the players in the "injured" and "non-injured" groups by means of the model, to determine the observed

and predicted frequencies for injury amongst the youth soccer players. Using this classification table documenting the validity of the predicted probabilities, the sensitivity and specificity of the prediction model can be evaluated. The overall correct percentage of prediction will also be determined.

Comparison will also be done to establish differences between the different age groups and between the school and club players for all the testing. The following formula by Cohen (1988) will be used to determine effect sizes of the difference between the means of any two groups:

$$d = \frac{|\bar{x}_1 - \bar{x}_2|}{s}$$

$\bar{x}_1$ is the mean of group one and $\bar{x}_2$ is the mean of group two. $s = \frac{1}{2} (S1+S2)$, where S1 and S2 are the standard deviation of the two groups. Cohen gives the following guidelines for the interpretation of the effect size:

$d = 0.2$ (Small effect)

$d = 0.5$ (Medium effect)

$d = 0.8$ (Large effect).

Data with a large effect is considered to have practical significance. As these are guidelines for interpretation, the decision was made that a d-value of 0.75 will be considered to have a large effect size. Injuries will also be expressed as injuries/1000 playing hours for the purpose of the comparisons with previous epidemiological research.

4.6 SUMMARY

This chapter contained a detailed description of the empirical investigation that is used for this research project. A description was given of the participants, the biomechanical, proprioceptive and plyometric test battery, the injury clinics and exposure recording as well as the statistical method to be used.

The next chapter will contain the results from the epidemiological research on the school and club teams used for this research. It will also contain the results of the proprioceptive, plyometric and biomechanical testing that was conducted on the participants. There will also be comparisons drawn between the different age groups as well as between the club and school players

CHAPTER 5

RESULTS AND DISCUSSION: PHYSICAL PROFILING AND EPIDEMIOLOGY

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CHAPTER 5

RESULTS AND DISCUSSION: PHYSICAL PROFILING AND EPIDEMIOLOGY

5.1 INTRODUCTION

This chapter contains the results of the empirical investigation. It contains descriptive results of the biomechanical, proprioceptive and plyometric testing that was conducted on the school and club players. The biomechanical results are discussed for the lower leg area, the knee area, the hip and groin area, the lumbo-pelvic area and the neurodynamic area. It also contains comparisons between the results of different age groups for these areas as well as comparisons between club and school players. The comparisons between different age groups and club and school players are important to note differences and also similarities between groups. The differences will be measured using Cohen's d-values and effect sizes (Cohen, 1988). These differences and similarities will then be used to create a biomechanical profile of South African school, club and youth (combined club and school players) players. The biomechanical profile will also be compared to a research reported by Serfontein and Spamer (2008), who did exactly the same biomechanical, proprioceptive and plyometric evaluation on 38 U/17 club players from the Costa Papi Soccer Academy. A biomechanical profile will be created for each age group of school and club players for comparative purposes in future research. The biomechanical profile is important when researching predictors of injury, as injured players will potentially differ from the uninjured players, making the creation of a

prediction model based on biomechanical parameters possible. A comprehensive description of the epidemiology of the recorded injuries will also be given. These epidemiological results will be compared to existing epidemiological research on youth players, to determine any differences and similarities. Comparisons between different age groups, as well as between club and school players will also be done to create an injury profile for club, school and youth players in South Africa. The correlation between non-contact injuries and biomechanical dysfunction will also be examined.

5.2 RESULTS AND DISCUSSION: PLATINUM STARS PLAYERS

The results for the proprioceptive and plyometric testing of the Platinum Stars players will now be discussed. Comparisons will be made between the U/17, U/18 and U/19 groups for this testing, discussing the findings and also practically significant differences (d-values) between the groups. The results of the biomechanical evaluation for the different areas will then be reviewed for the different age groups and comparisons between the age groups will also be discussed. Finally, the results of the epidemiological study will be discussed, with comparisons between the groups, as well as comparisons with previous research studies.

5.2.1 Proprioceptive and Plyometric Testing

The players were tested with a single limb stance test for balance and proprioception and the sergeant jump test using the wall mark method to test plyometric strength. The ratios of Dominant limb: Bilateral height (D/Bil), Non Dominant limb: Bilateral height

(ND/Bil) and the sum of Dominant and Non-Dominant: bilateral height (D+ND/Bil) are also given and will be used for prediction purposes as well.

Table 5.1 shows the results of the three age groups of Platinum Stars players for the proprioceptive and plyometric testing part of the test battery. The combined totals for the three groups used for the discussion are reported in Table 5.27. The mean age of the players increases from the U/17 group to the U/19 group, as is expected. There is, however, a lesser age difference between the U/18 and U/19 players than between the U/17 and U/18 players. All three groups show a strong propensity towards being right foot dominant (81.8%, 83.3% and 76.2%), with very few left footed players present in all teams. With the single limb stance test, between 57.1% and 66.7% of the U/19 group failed the test, performing better than the other two age groups (Between 72.7% and 81.8% in U/17's and between 61.1% and 72.2% in U/18's). This could possibly be attributed to decreased proprioception occurring in adolescents during increased growth periods such as that occurring at U/17 and U/18 age levels. Increased variation in postural stability (decreased proprioception) is associated with an altered neuromuscular control strategy; increased intersegmental joint forces and corresponding increased forces developed about articular, ligamentous and muscular structures (Murphy *et al.*, 2003). Armstrong and McManus (1996) argue that a loss of muscle flexibility occurs during rapid growth, with joint becoming progressively inflexible. Neural maturation also increases with age, leading to more co-ordinated recruitment of muscle fibres (Armstrong and Welsman, 1997). This joint inflexibility combined with lacking neural maturation leads to decreased proprioception amongst adolescents in fast growth phases. The

plyometric results show that the U/18 group outperformed both the U/17 and U/19 group with bilateral and unilateral jumping. The D+ND/Bil, D/Bil and ND/Bil ratios showed fairly similar results for the three age groups.

Table 5.1 Descriptive statistics for age dominance, proprioception and plyometric results of Platinum Stars soccer players

Number	Platinum Stars U/17				Platinum Stars U/18				Platinum Stars U/19			
	22				18				21			
	Mean		Std Dev		Mean		Std Dev		Mean		Std Dev	
AGE:	15.636		0.72		17.388		0.92		18.000		0.84	
RIGHT LIMB DOMINANCE %	81.8		39		83.3		38		76.2		44	
BALANCE	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
Single Limb Stance	1.727	0.460	1.818	0.40	1.722	0.460	1.611	0.50	1.667	0.480	1.571	0.51
PLYOMETRICS	Mean		Std Dev		Mean		Std Dev		Mean		Std Dev	
Bilateral (cm)	34.409		6.61		41.778		8.54		39.190		7.90	
Dominant (cm)	26.409		5.18		30.611		6.63		27.952		8.08	
Non-Dominant (cm)	26.000		5.96		32.167		7.03		28.857		7.20	
D+ND/Bil	1.531		0.18		1.507		0.15		1.448		0.21	
D/Bil	0.772		0.09		0.737		0.11		0.710		0.13	
ND/Bil	0.759		0.12		0.770		0.07		0.738		0.12	

Table 5.2 shows the comparative results between the different age groups of the Platinum Stars youth players for proprioceptive and plyometric testing. There are practically significant differences of large effect size in age between the U/17 and U/18 groups as well as between the U/18 and U/19 groups. The age difference between the U/18 and U/19 groups is less, but still has a medium effect influence on practical significance ($d=0.70$). The only other differences with large effect sizes of practical significance were the plyometric comparisons for bilateral ($d=0.97$) as well as non dominant limb ($d=0.95$) between the U/17 and U/18 groups. Limb dominance comparisons showed a less than small effect size differences ($d<0.2$) between the three different age groups when compared to each other (U/17 vs U/18, U/18 vs U/19 and U/17 vs U/19). All three groups had an overwhelming right limb dominance, ranging between 76.2% and 83.3% of players (Table 5.1).

Table 5.2 Comparative results for age, limb dominance, proprioception and plyometric testing of Platinum Stars soccer players

	Platinum Stars U/17 v U/18		Platinum Stars U/17 v U/19		Platinum Stars U/18 vs U/19	
	d Values		d Values		d Values	
AGE:	-2.14		-3.03		-0.70	
DOMINANCE L=1/ R=2	-0.04		0.14		0.17	
BALANCE	Left	Right	Left	Right	Left	Right
Single Limb Stance	0.01	0.46	0.13	0.54	0.12	0.08
PLYOMETRICS						
Bilateral (cm)	-0.97		-0.66		0.31	
Dominant (cm)	-0.71		-0.23		0.36	
Non-Dominant (cm)	-0.95		-0.43		0.47	
D+ND/Bil	0.15		0.42		0.33	
D/Bil	0.35		0.56		0.22	
ND/Bil	-0.12		0.17		0.34	

$d=0.2$ (small effect) $d=0.5$ (medium effect) $d=0.8$ (large effect)

5.2.2 Summary of Proprioceptive and Plyometric Testing

There were 61 players from three teams (U/17, U/18, U/19) from Platinum Stars involved in this research project. The combined results for the three age groups are shown in Table 5.27. The mean age of the club players was 16.97 years. Between 67.2% and 70.5% of the players failed a single limb stance test, with combined mean values of 1.705 and 1.672 for left and right sides. The majority of players (80.3%) were right limb dominant and the balance tests indicate that the dominant legs had better balance than the non-dominant legs. The mean bilateral leg jump height was 38.23cm. Talented U/16 players tested by Badenhorst (1998) showed similar plyometric results with a mean bilateral value of 38.37cm and U/18 rugby players evaluated by Serfontein (2006) also had bilateral mean values of 38.21cm. The U/17 club soccer players (mean age 16.07 years) recorded by Serfontein and Spamer (2008) had only a mean value of 33.5cm with bilateral jump height. The mean results for the Platinum Stars players showed a dominant leg jump height of 28.18cm, with a non-dominant leg jump height of 28.80cm (Table 5.27).

5.2.3 Biomechanical Evaluation

As described in chapter 4, the biomechanical results are divided into five areas. These are: the foot and lower leg area; the knee area; the upper leg and hip area; the Lumbo-pelvic area and the Neurodynamic area. Each area also contains a combined dysfunction score. This combined dysfunction score is an indication of the total amount of dysfunction for a particular area and is combined out of the dysfunction scores noted for the individual tests.

Table 5.3 shows the results of the lower leg components of the biomechanical evaluation for the Platinum Stars players. The areas with mean values indicating abnormality in the majority of players in all age groups were the Achilles tendon test with a combined mean for all age groups of 1.803 for the left side and 1.918 for the right side (Table 5.28) and the toe positional test (between 44.5% and 89.9% of all players). Tests that exhibited mean values close to normal (normal = 1) for all age groups were the supination component of the rear foot positional tests (means between 1.056 and 1.227), the high arch component of the foot arch test (means between 1.046 and 1.095), the hypermobility component of the foot mobility test (means between 1.000 and 1.091) and previous injury questionnaires. The combined dysfunction score for the U/17 group (mean left = 4.091 and mean right = 4.591) was lower than that of the U/18 (mean left = 5.167 and mean right = 5.889) and U/19 (mean left = 5.190 and mean right = 5.810) groups. These two age groups showed fairly similar results for this dysfunction score. A summary of the combined biomechanical profile for the lower leg area for club players is given in paragraph 5.2.4.

Table 5.3 Descriptive statistics for foot and lower leg biomechanical results of Platinum Stars soccer players

	Platinum Stars U/17				Platinum Stars U/18				Platinum Stars U/19			
FOOT AND LOWER LEG	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
ACHILLES TENDON SUPPLENESS TEST	1.682	0.57	1.864	0.64	1.889	0.58	1.944	0.54	1.857	0.57	1.952	0.59
FOOT LONGITUDINAL TEST												
High Arch	1.046	0.21	1.046	0.21	1.056	0.24	1.056	0.24	1.095	0.30	1.095	0.30
Low Arch	1.636	0.49	1.636	0.49	1.556	0.51	1.611	0.50	1.619	0.50	1.667	0.48
FORE FOOT	1.273	0.46	1.273	0.46	1.556	0.51	1.556	0.51	1.429	0.51	1.429	0.51
REAR FOOT STANDING TEST												
Pronation	1.409	0.50	1.500	0.51	1.556	0.51	1.778	0.42	1.571	0.51	1.714	0.46
Supination	1.182	0.39	1.227	0.43	1.056	0.24	1.056	0.24	1.095	0.30	1.143	0.36
REAR FOOT LYING TEST												
Pronation	1.318	0.48	1.409	0.50	1.556	0.51	1.778	0.43	1.571	0.51	1.714	0.46
Supination	1.182	0.40	1.227	0.43	1.056	0.24	1.056	0.24	1.095	0.30	1.095	0.30
TRANSVERSE ARCH	1.409	0.50	1.409	0.50	1.389	0.50	1.444	0.51	1.286	0.46	1.286	0.46
MID-FOOT MOBILITY TEST												
Hypomobility	1.364	0.49	1.455	0.60	1.389	0.50	1.500	0.51	1.524	0.51	1.619	0.50
Hypermobility	1.091	0.29	1.091	0.29	1.000	0.00	1.000	0.00	1.048	0.22	1.000	0.00
TOES	1.455	0.51	1.455	0.51	1.889	0.32	1.889	0.32	1.714	0.46	1.762	0.44
PREVIOUS INJURY	1.227	0.43	1.091	0.53	1.222	0.43	1.222	0.43	1.286	0.46	1.286	0.46
DYSFUNCTION SCORE /10	4.091	1.87	4.591	2.11	5.167	2.50	5.889	2.00	5.190	1.40	5.810	1.44

Table 5.4 shows a comparison between the different age groups for the lower leg components of the biomechanical evaluation. With the comparison between the U/17 and U/18 group, there were only large effect practically significant differences for the toe positional test left and right ($d=1.05$) and the pronation component for the rear foot lying test of the right foot ($d=0.79$). The right foot Achilles tendon suppleness test, bilateral foot arch components, bilateral transverse arch test, bilateral hypomobility components of the foot mobility testing and the left foot previous injury questionnaire showed differences of less than small effect on practical significance, indicating large similarity between the groups.

In the comparison between the U/17 and U/19 groups, there were no tests with high practically significant difference between the two age groups. There were differences of less than small effect sizes ($d<0.2$) for the right Achilles suppleness test, the bilateral low arch components of the foot longitudinal arch test, the hypermobility component of the left mid-foot mobility test and the left previous injury history questionnaire.

When the U/18 and U/19 groups are compared for the lower leg portion of the biomechanical evaluation, there were no tests that showed large effect practically significant differences between the two groups. All the rest of the lower leg biomechanical tests reflected smaller than medium effect sized differences between the groups, with most of the tests showing less than small effect sized differences.

Table 5.4 Comparative results for foot and lower leg evaluation of Platinum Stars soccer players

	Platinum Stars U/17 vs U/18		Platinum Stars U/17 vs U/19		Platinum Stars U/18 vs U/19	
	d Values		d Values		d Values	
FOOT AND LOWER LEG	Left	Right	Left	Right	Left	Right
ACHILLES TENDON SUPPLENESS TEST	-0.36	-0.14	-0.31	-0.14	0.06	-0.01
FOOT LONGITUDINAL TEST						
High Arch	-0.05	-0.05	-0.20	-0.20	-0.15	-0.15
Low Arch	0.16	0.05	0.03	-0.06	-0.12	-0.11
FORE FOOT	-0.58	-0.58	-0.32	-0.32	0.25	0.25
REAR FOOT STANDING TEST						
Pronation	-0.29	-0.59	-0.32	-0.44	-0.03	0.14
Supination	0.40	0.51	0.25	0.21	-0.15	-0.29
REAR FOOT LYING TEST						
Pronation	-0.48	-0.79	-0.51	-0.64	-0.03	0.14
Supination	0.39	0.51	0.25	0.33	-0.15	-0.13
TRANSVERSE ARCH	0.04	-0.07	0.26	0.26	0.22	0.33
MID-FOOT MOBILITY TEST						
Hypomobility	-0.05	-0.08	-0.32	-0.30	-0.27	-0.24
Hypermobility	0.63	0.63	0.17	0.63	-0.43	0.00
TOES	-1.05	-1.05	-0.54	-0.65	0.45	0.33
PREVIOUS INJURY	0.01	-0.27	-0.13	-0.39	-0.14	-0.14
DYSFUNCTION SCORE /10	-0.50	-0.66	-0.67	-0.69	-0.01	0.08

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

In summary the biomechanical profile for the lower leg area of the three age groups can be described as follows: The profile of the Platinum Stars U/17 players (Table 5.3) showed dysfunction for the Achilles suppleteness test, with shortened Achilles tendons. They also presented with low foot arches. Between 31.8% and 45.5% of the players also presented with pronated rear feet, transverse arch dysfunction, hypomobile mid-foot joints and dysfunctional toe position or callus formation of big toes. The rest of the tests showed normal biomechanical alignment.

The lower leg biomechanical profile for the U/18 players from Platinum Stars (Table 5.3) shows a player with dysfunction of the Achilles tendon suppleness test, excessive right rear foot pronation and toe positional dysfunction. Between 44.4% and 63.6% of the players also exhibit forefoot positional dysfunction, right foot transverse arch dysfunction, flat longitudinal foot arches and reduced mid-foot mobility on the right.

The biomechanical profile of U/19 players from Platinum Stars (Table 5.3) exhibits dysfunction of the Achilles tendon with decreased suppleness and dysfunction of the toe position of the right side. Between 52.4% and 71.4% of the players also present with excessive rearfoot pronation, hypomobility of the mid-foot joints, low foot longitudinal arches and left sided toe dysfunction.

The biomechanical differences between left and right sides can probably be attributed to limb dominance and the effects this type of mostly unilateral stress while playing soccer has on lower limb biomechanics. This difference between the left and right sides also appear to increase with age, showing that prolonged exposure could increase biomechanical abnormality due to the nature of limb dominance in the game.

Table 5.5 shows the biomechanical results for the knee area of the players from Platinum Stars. The results for the different age groups are fairly similar for this area. In the Quadriceps component of the Thomas test, the players from the U/17, U/18 and U/19 groups all predominantly show mean scores of close to 2, indicating dysfunction. This is indicative of tightness of the quadriceps muscle. Mean values for the patella quint test of

all age groups indicate that between 45.5 and 72.2% of the players presented with excessive patella squinting of the knee. The other knee test all showed mean values of close to 1 (normal), indicating little dysfunction with the tests. The mean values for the combined dysfunction score for the knee area ranged between 1.910 and 2.389. With a maximum dysfunction score of 8 in this area, these mean values indicate fairly low levels of dysfunction in the knee area of the players from Platinum Stars.

Table 5.6 reflects the comparisons of the results from the different age groups of Platinum Stars FC. In comparisons between the different age groups, there were no large effect practically significant differences for any of the tests in the knee area. In the comparison between the U/17 and U/19 groups, all the d-values were 0.2 or less indicating less than small effect sizes. These two groups are thus practically similar for biomechanics of the knee area. When the U/17 and U/18 groups are compared all the differences were of small effect size or less, indicating homogenous results between the two groups. In the comparison between the U/18 and U/19 groups, there were differences of small effect size or less for all tests.

Table 5.5 Descriptive statistics for knee area biomechanical results of Platinum Stars soccer players

KNEE	Platinum Stars U/17				Platinum Stars U/18				Platinum Stars U/19			
	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
THOMAS TEST: QUADS	2.046	0.65	1.955	0.65	2.000	0.69	1.944	0.64	1.905	0.62	2.000	0.63
KNEE Q-ANGLE	1.045	0.21	1.045	0.21	1.000	0.00	1.000	0.00	1.048	0.22	1.048	0.22
PATELLA SQUINT	1.455	0.51	1.591	0.50	1.556	0.51	1.722	0.46	1.619	0.50	1.667	0.48
PATELLA TILT	1.091	0.29	1.136	0.35	1.167	0.38	1.278	0.46	1.143	0.36	1.095	0.30
KNEE HEIGHT	1.045	0.21	1.045	0.21	1.167	0.38	1.167	0.38	1.095	0.30	1.095	0.30
VMO	1.091	0.29	1.182	0.40	1.111	0.32	1.056	0.24	1.143	0.36	1.143	0.36
PREVIOUS INJURY	1.091	0.29	1.227	0.43	1.056	0.24	1.222	0.55	1.143	0.36	1.238	0.44
DYSFUNCTION SCORE /8	1.910	0.97	2.227	1.23	2.056	1.26	2.389	1.29	2.095	1.00	2.286	1.23

Table 5.6 Comparative results for knee area evaluation of Platinum Stars soccer players

KNEE	Platinum Stars U/17 vs U/18		Platinum Stars U/17 vs U/19		Platinum Stars U/18 vs U/19	
	d Values		d Values		d Values	
	Left	Right	Left	Right	Left	Right
THOMAS TEST: QUADS	0.07	0.02	0.22	-0.07	0.15	-0.09
KNEE Q-ANGLE	0.43	0.43	-0.01	-0.01	-0.43	-0.43
PATELLA SQUINT	-0.20	-0.27	-0.33	-0.15	-0.12	0.12
PATELLA TILT	-0.23	-0.35	-0.16	0.13	0.07	0.48
KNEE HEIGHT	-0.41	-0.41	-0.20	-0.20	0.21	0.21
VMO	-0.07	0.40	-0.16	0.10	-0.09	-0.29
PREVIOUS INJURY	0.13	0.01	-0.16	-0.02	-0.29	-0.03
DYSFUNCTION SCORE /8	-0.13	-0.13	-0.19	-0.05	-0.03	0.08

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

The biomechanical profile for the knee area of the Platinum Stars U/17 players showed mean test values (L = 2.046, R = 1.955) indicating dysfunction for the quadriceps component of the Thomas test, with decreased length of the muscle. Between 45.5% (left side) and 59.1% (right side) of players also exhibited dysfunction of the patella squint test, with abnormal, laterally deviated patellar position. Between 4.5% and 22.7% of players showed dysfunction with the patella tilt, VMO, knee height, Q-angle and previous injury history. This indicates very little dysfunction with these tests.

The U/18 players exhibited dysfunctional mean values of the quadriceps length test (L=2.00, R=1.944), with decreased muscle lengths present in most players. Between 55.6% and 72.2% of the players also showed dysfunction with the patella squint test. The other tests in the knee area all had mean values very close to normal. The combined dysfunction scores calculated out of 8 were 2.056 (Left) and 2.389 (Right), showing little combined dysfunction in the knee area.

The U/19 players showed a similar profile to the U/18 group, also having decreased length of the quadriceps muscles. Between 61.9% and 66.7% of the players also showed problems with the patella squint test with results close to normal for the other tests of the knee area.

The gross profile of all age groups for the knee area thus shows decreased quadriceps length with between 45.5% and 66.7% of the players showing abnormal patella squinting. The rest of the tests had values close to normal. Generally, there was very little

dysfunction in the knee area, as is reflected by the combined knee dysfunction score calculated out of 8.

The results for the biomechanical evaluation of the hip area for the Platinum Stars youth players are shown in Table 5.7. It is important to remember that the majority of the tests in the hip area are calculated with a three point scale, where “1” is normal, “2” indicates dysfunction and “3” indicates severe dysfunction. In the U/17 group, the results for right ITB component of the Thomas Test (mean = 1.955), the Iliopsoas component of the Thomas Test (Left mean = 1.727 and Right mean = 1.773), adductor length test (mean = 1.818) and the Hip External Rotation test (Left mean = 2.455 and Right mean = 2.273) all show mean values of a dysfunctional nature. The mean values for the gluteal muscle length test (mean=1.682) also indicate some dysfunction in this area with shortened gluteal muscles. The combined dysfunction score for this area had mean values of 4.455 for the left side and 5.000 for the right side. The combined dysfunction score for the hip area is calculated out of 13. For this area, it is apparent that there is more dysfunction of the right side than the left, which could be attributed to the nature of play where players favour a certain leg more, due to limb dominance. This excludes the Hip External rotation test, where the right side shows better mobility than the left. This could be attributed to the externally rotated position of the leg that is used during passing manoeuvres on the field of play. The right leg is used for passing more often and is thus in an externally rotated position more often, creating more mobility into the hip external rotation position.

The results for the U/18 players show similar results to the U/17 group with the right ITB component of the Thomas test and bilateral hip external rotation values exhibiting dysfunctional mean values. The results for the gluteal muscle length test and left ITB component of the Thomas test also indicate that between 61.1% (11 of 18 players) and 83.3% (15 of 18 players) of players had dysfunction with these tests.

In the U/19 group the mean values for Right ITB component of the Thomas test, the right gluteal muscle length test and the hip external rotation test were indicative of dysfunctional results in these tests. The results of Iliopsoas component of the Thomas test, as well as the left ITB and left Gluteal muscle length tests, all indicate that between 50% (9 of 18 players) and 66.7% (12 of 18 players) of the players in the group exhibited dysfunctional muscle lengths with these tests. The U/19 players exhibited a similar pattern of tightness to the other groups, with the right side generally being tighter than the left, except with the hip external rotation tests where the left side showed more tightness.

Table 5.8 shows a comparison between the different age groups for the hip area biomechanical results. In a comparison between the U/17 and U/18 groups, there were statistically significant differences between the two groups for both left and right Iliopsoas lengths and left hip internal rotation results. The U/18 group was more supple than the U/17 group with less dysfunction on the combined dysfunction score as well. The hip external rotation test also showed differences of a medium effect size ($d > 0.5$), with the U/17 group showing more tightness than the U/18 group.

In the comparison between the U/17 and U/19 groups, there were no differences of practical significance. Comparisons for the left Iliopsoas length test, right Gluteal length test, left hip internal rotation, left hip external rotation and left leg previous injury all showed differences of small effect size on practical significance.

In the comparison between the U/18 and U/19 groups, there were two tests with differences of practical significance. These were right leg Iliopsoas component of the Thomas test and the left hip external rotation length test. There were also differences of medium effect size for left leg ITB, left leg Iliopsoas, left hip internal rotation test and right leg hip external rotation test.

Table 5.7 Descriptive statistics for hip area biomechanical results of Platinum Stars soccer players

	Platinum Stars U/17				Platinum Stars U/18				Platinum Stars U/19			
HIP	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
ITB	1.500	0.60	1.955	0.72	1.667	0.49	2.000	0.69	1.429	0.51	1.952	0.74
ILIOPSOAS	1.727	0.77	1.773	0.69	1.222	0.43	1.222	0.43	1.571	0.75	1.667	0.66
GLUTEAL MUSCLES	1.682	0.84	1.682	0.84	1.556	0.70	1.611	0.61	1.762	0.77	1.952	0.74
ADDUCTOR LENGTH	1.818			0.91	1.667			0.77	1.571			0.68
HIP INTERNAL ROTATION	1.227	0.43	1.273	0.46	1.000	0.00	1.167	0.38	1.095	0.30	1.238	0.44
HIP EXTERNAL ROTATION	2.455	0.67	2.273	0.70	2.056	0.64	1.889	0.68	2.619	0.50	2.333	0.58
PREVIOUS INJURY	1.045	0.21	1.182	0.40	1.333	0.59	1.333	0.69	1.143	0.36	1.191	0.51
DYSFUNCTION SCORE /13	4.455	2.46	5.000	2.94	3.444	1.92	3.889	2.49	4.190	2.44	4.952	2.20

Table 5.8 Comparative results for hip area evaluation of Platinum Stars soccer players

	Platinum Stars U/17 vs U/18		Platinum Stars U/17 vs U/19		Platinum Stars U/18 vs U/19	
	d Values		d Values		d Values	
HIP	Left	Right	Left	Right	Left	Right
ITB	-0.31	-0.06	0.13	0.00	0.48	0.07
ILIOPSOAS	0.84	0.98	0.21	0.16	-0.59	-0.82
GLUTEAL MUSCLES	0.16	0.10	-0.10	-0.34	-0.28	-0.51
ADDUCTOR LENGTH	0.18		0.13		0.13	
HIP INTERNAL ROTATION	1.06	0.25	0.36	0.08	-0.63	-0.17
HIP EXTERNAL ROTATION	0.61	0.56	-0.28	-0.09	-0.99	-0.71
PREVIOUS INJURY	-0.72	-0.28	-0.34	-0.02	0.40	0.24
DYSFUNCTION SCORE /13	0.46	0.41	0.11	0.02	-0.34	-0.45

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

With the hip area biomechanical test results, it is noticeable that the U/17 and U/19 groups showed similar characteristics, with the U/18 group showing less dysfunction in most tests. There was excessive hip external rotation dysfunction in all groups and also excessive ITB tightness of the right side amongst all the groups. There was generally also more tightness of the right side with most tests, except for the hip external rotation test, where the left side was generally tighter. This could be ascribed to the majority of players being right foot dominant and the externally rotated position of the leg during passing, which increases the range of motion of external rotation on the right more than on the left.

The biomechanical results for the Lumbo-pelvic area of the Platinum Stars youth teams is shown in Table 5.9. In the results for the U/17 group, it can be seen that the bilateral pelvis positional test shows a dysfunctional mean value (1.955), indicative of excessive anterior pelvic tilt in most players. The results for ASIS, PSIS, rami and cleft all indicate that 59.1% of the players presented with asymmetry of the Sacro-iliac joint. The similarity between the results of these tests indicates the possibility of combining them into one value, which could be called Sacro-iliac dysfunction. The mean values of the sacral rhythm test and the leg length discrepancy test also indicate that between 59.09% and 63.6% of the players had dysfunction in these tests. The mean result for the combined dysfunction score of the lumbo-pelvic area was 6.955 for the left side and 6.909 for the right side. This score is calculated out of 21, showing a relatively low level of dysfunction amongst the players for this area.

The results for the U/18 group showed that 44.4% of the players presented with ASIS, PSIS, Rami, Cleft and sacral rhythm dysfunction. These tests all had the same values, once again suggesting that these could be combined into a Sacro-iliac dysfunction score, consisting of the average of the individual tests results. The lumbar flexion test showed a mean value of 1.944, which is close to a dysfunctional value of 2. The pelvis bilateral test results indicated that 61.11% (11 out of 18 players) of the players had an excessive anterior pelvic tilt. The combined dysfunction score for the left side had a mean value of 5.389 and the right side 5.222. These values indicate less dysfunction in the U/18 group than in the U/17 group.

The U/19 group had a dysfunctional mean value for the pelvis bilateral test (2.048), indicating excessive anterior pelvic tilt in all players. The ASIS, PSIS, Rami, Cleft and sacral rhythm tests all had mean values of 1.524, once again indicating the possibility of combining these test results into a single Sacro-iliac joint dysfunction score. Between 38.09 and 61.90% of the players exhibited dysfunction in this test area, as well as the leg length difference test and the lumbar extension and flexion tests. The combined dysfunction score had results that indicated more dysfunction on the left than the right. This pattern is similar to the U/17 and U/18 groups, which also showed more dysfunction on the left than the right side. This unilaterally higher dysfunction could be attributed to limb dominance and the way players play as a result of this, exerting more strain on the one side of the body than the other with passing and kicking actions.

Table 5.9 Descriptive statistics for lumbo-pelvic area biomechanical results of Platinum Stars soccer players

	Platinum Stars U/17				Platinum Stars U/18				Platinum Stars U/19			
LUMBO PELVIC AREA	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
LEG LENGTH	1.727			0.70	1.556			0.62	1.667			0.66
ASIS	1.591			0.50	1.444			0.51	1.524			0.51
PSIS	1.591			0.50	1.444			0.51	1.524			0.51
RAMI	1.591			0.50	1.444			0.51	1.524			0.51
CLEFT	1.591			0.50	1.444			0.51	1.524			0.51
PELVIS BILATERAL POSITION	1.955			0.78	1.722			0.67	2.048			0.74
THORACO LUMBAR FASCIA	1.318	0.48	1.222	0.43	1.222	0.43	1.167	0.38	1.095	0.30	1.095	0.30
SACRUM RHYTHM	1.636			0.49	1.444			0.51	1.524			0.66
EXTENSION	1.409			0.50	1.278			0.46	1.492			0.60
FLEXION	1.636			0.49	1.944			0.80	1.667			0.58
ROTATION	1.409	0.50	1.167	0.38	1.167	0.38	1.111	0.32	1.286	0.46	1.238	0.44
SIDE FLEXION	1.136	0.35	1.167	0.38	1.167	0.38	1.111	0.32	1.333	0.48	1.286	0.46
LUMBAR CORONAL	1.409			0.50	1.389			0.50	1.429			0.51
LUMBAR SAGGITAL	1.227			0.43	1.111			0.32	1.381			0.50
DYSFUNCTION SCORE /21	6.955	3.62	6.909	3.53	5.389	3.47	5.222	3.30	5.571	3.67	5.476	3.67

Table 5.10 shows the comparison between the different age groups of Platinum Stars. In the comparison between the U/17 and U/18 groups, there were no differences with large effect practical significance. There were some tests that showed differences of medium effect size, namely the rotational tests to left and right. The rest of the tests all showed differences of small effect size or less, indicating very homogenous results for this area in the U/17 and U/18 groups.

When the U/18 and U/19 groups were compared, there were no large effect practically significant differences between the two age groups. There was only one test that showed a difference of medium effect size (Left Rotation test) with all other tests showing differences of small effect size or less. There is therefore generally little difference between the U/18 and U/19 groups of Platinum Stars for the lumbo-pelvic area.

When the U/17 and U/19 groups were compared there were no large effect practically significant differences. There was only one test that presented with differences of medium effect size (Lumbar Saggital view), with the rest of the tests only showing differences of small effect size or less. This indicates the similarity between the U/17 and U/19 players for the lumbo-pelvic area.

Table 5.10 Comparative results for lumbo-pelvic area evaluation of Platinum Stars soccer players

	Platinum Stars U/17 vs U/18		Platinum Stars U/18 vs U/19		Platinum Stars U/17 vs U/19	
	d Values		d Values		d Values	
LUMBO PELVIC AREA	Left	Right	Left	Right	Left	Right
LEG LENGTH	0.19		0.02		-0.17	
ASIS	0.20		0.04		-0.16	
PSIS	0.20		0.04		-0.16	
RAMI	0.20		0.04		-0.16	
CLEFT	0.20		0.04		-0.16	
PELVIS BILATERAL POSITION	0.32		-0.12		-0.46	
THORACO LUMBAR FASCIA	0.21	0.25	0.57	0.47	0.35	0.21
SACRUM RHYTHM	0.29		0.13		-0.16	
EXTENSION	0.27		-0.04		-0.28	
FLEXION	-0.48		-0.06		0.40	
ROTATION	0.55	0.62	0.26	0.27	-0.28	-0.33
SIDE FLEXION	-0.08	0.20	-0.47	-0.24	-0.39	-0.45
LUMBAR CORONAL	0.04		-0.04		-0.08	
LUMBAR SAGGITAL	0.31		-0.33		-0.66	
DYSFUNCTION SCORE /21	0.44	0.49	0.38	0.40	-0.05	-0.07

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Generally, there were very few differences between the three age groups and none of the differences were of large effect practical significance. This is important in the search for injury predictors, as injured players would potentially have test results that would differentiate between them and the uninjured players, who present uniformly in this biomechanical area.

Table 5.11 shows the results for the neurological part of the biomechanical evaluation of the Platinum Stars players. It also reflects the mean value for the total dysfunction score of each group, which consists of the sum of the individual area dysfunction scores. The U/17 group presented with a dysfunctional mean value for the prone knee bend (mean = 2.000), indicating neural tension present in the players for the L4 nerve root. The straight

leg raise and slump tests showed mean values close to normal. The total dysfunction score had a mean value of 19.000 for the left side of the body and 20.318 for the right side.

The U/18 group presented with mean values close to dysfunctional (dysfunction = 2) for the left straight leg raise (mean = 1.667) and left prone knee bend tests (mean = 1.611). The slump test had mean values close to normal for both left and right sides. The combined dysfunction score had a mean value of 17.444 for the left side of the body and 18.833 for the right side, showing less dysfunction in the U/18 group than the U/17.

The U/19 group showed results with mean values ranging between dysfunction and severe dysfunction for the prone knee bend test (Left mean = 2.381 and Right mean = 2.619). Between 38.10% and 42.86% of players presented with dysfunction of the straight leg raise test according to the test results (Left mean = 1.571 and Right mean = 1.524). The slump test had mean values close to normal (normal = 1). The total dysfunction score for the U/19 group had a mean value of 19.143 for the left side and 20.810 for the right side.

The comparison between the different age groups of Platinum Stars for the neurological part of the biomechanical evaluation is shown in Table 5.12. In the comparison between the U/17 and U/18 groups there are no large effect practically significant differences. There were differences of small effect size for the left prone knee bend, slump and right

straight leg raise neurological tests. The total combined dysfunction score also had a difference of small effect size between the two groups.

In the comparison between the U/18 and U/19 groups there was one differences of large effect size on practical significance (Right Prone knee bend). There were differences of medium effect size for the neurological dysfunction score of the right side. The rest of the neurological tests al showed differences of small effect size. The total combined dysfunction scores had differences of less than small effect size.

When the U/17 and U/19 groups are compared, there were large effect practically significant differences for the prone knee bend tests for both the left and right sides. The neurological dysfunction results showed differences of medium effect size and there were differences of small effect size for the combined total dysfunction score. The U/19 group showed excessive tightness of the L4 nerve root as tested in the prone knee bend test when compared to the other age groups. They also showed the highest scores in the total combined dysfunction score, followed by the U/17 group and then the U/18 group. Possible reasons for this occurrence could be attributed to an increased growth rate in the U/17 groups leading to temporary nerve length dysfunction, which normalises at age 18. The increase at U/19 age could then be attributed to increased exposure and an increase in previous injuries with higher age.

Table 5.11 Descriptive statistics for neurodynamic biomechanical results of Platinum Stars soccer players

	Platinum Stars U/17				Platinum Stars U/18				Platinum Stars U/19			
NEURODYNAMICS	L Mean	STD Dev	R Mean	STD Dev	L Mean	STD Dev	R Mean	STD Dev	L Mean	STD Dev	R Mean	STD Dev
STRAIGHT LEG RAISE	1.318	0.57	1.273	0.46	1.667	0.76	1.389	0.70	1.571	0.75	1.524	0.75
PRONE KNEE BEND	2.000	0.87	2.000	0.87	1.611	0.78	1.889	0.83	2.381	0.74	2.619	0.59
SLUMP	1.273	0.46	1.273	0.46	1.111	0.32	1.167	0.51	1.143	0.36	1.143	0.36
DYSFUNCTION SCORE /6	1.591	1.26	1.591	1.18	1.389	1.50	1.444	1.39	2.095	1.04	2.286	1.06
TOTAL DYSFUNCTION SCORE /58	19.000	5.57	20.318	6.59	17.444	6.49	18.833	6.56	19.143	5.13	20.810	5.69

Table 5.12 Comparative results for neurodynamic evaluation of Platinum Stars soccer players

	Platinum Stars U/17 vs U/18		Platinum Stars U/18 vs U/19		Platinum Stars U/17 vs U/19	
	d Values		d Values		d Values	
NEURODYNAMICS	Left	Right	Left	Right	Left	Right
STRAIGHT LEG RAISE	-0.52	-0.20	-0.38	-0.42	0.13	-0.19
PRONE KNEE BEND	0.47	0.18	-0.47	-0.77	-1.01	-1.03
SLUMP	0.41	0.22	0.32	0.32	-0.09	0.06
DYSFUNCTION SCORE /6	0.15	0.12	-0.44	-0.62	-0.56	-0.70
TOTAL DYSFUNCTION SCORE /58	0.26	0.23	-0.03	-0.08	-0.29	-0.32

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

5.2.4 Summary of biomechanical evaluation

Based on the biomechanical analysis of the lower leg and ankle area, the average club player presented with decreased Achilles Tendon suppleness, a normal or flat medial foot arch, a normal or hypomobile mid-foot joint and a normal or pronated rear foot. When compared with the results of Serfontein and Spamer (2008), who presented biomechanical results of U/17 Club players from the Costa Papic Soccer Academy, the players showed a similar decreased Achilles tendon length, normal or flat medial foot arches, normal or hypomobile foot arches and normal or pronated rear feet. The biomechanics of the foot function in a manner that a flat foot arch usually leads to increased rear foot pronation and prolonged mobilisation with flat arches could also lead to stiffening up of the mid-foot joint in the flattened position. Between 36.1% and 68.9% players also present with forefoot positional dysfunction, transverse arch dysfunction and toe positional dysfunction. Serfontein and Spamer (2008) showed similar results with some players presenting with toe dysfunction and transverse arch dysfunction. The toe positional dysfunction could be attributed to the excessive shortening of hip lateral rotators (Table 5.7) leading to an externally rotated leg with walking and running activities. This externally rotated leg with flat arches and rear foot pronation leads to excessive forefoot supination and a gait pattern where the medial part of the big toe is excessively stressed during mobilisation, leading to callus formation. The average club player also has not had any previous injuries

The profile of club players for the knee area show players presenting with tightening of the quadriceps muscles; normal Q-angle, normal patella tilt, normal knee height, normal

visual VMO:VL muscle ratios and no previous injuries to the knee area. Between 54.1% and 65.6% of players presented with abnormal patella squinting. Generally, there was very little dysfunction present in the knee area of club players. Serfontein and Spamer (2008) presented with similar low levels of dysfunction with only the Quadriceps length test of the Costa Papi Soccer Academy U/17 players showing mean results close to dysfunctional values (mean left = 1.500 and mean right = 1.605).

The profile for the hip area of club players shows players with shortening of hip external rotators and right ITB, no previous reported injuries and normal hip internal rotation ROM. Between 49.18% and 60.66% of players exhibited shortening of Gluteal muscles, Iliopsoas muscles, adductor muscles and left leg ITB. Players evaluated by Serfontein and Spamer (2008) exhibited this exact same pattern of tightness in the hip area, with mean dysfunction scores of 3.654 (Left) and 4.105 (Right). This unilateral ITB tightness could be attributed to limb dominance, with the right leg dominant players having the right leg in external rotation more often due to passing with the instep of the foot. This is also the cause of left external rotation being tighter, as the right leg is in an externally rotated position more often.

The Lumbo-pelvic profile for club players indicate that players present with an excessive anterior pelvic tilt, normal side flexion ROM, normal lumbar rotation ROM, normal Thoraco Lumbar fascia length, no scoliosis when viewed sagittally and normal lumbar extension ROM. Players evaluated by Serfontein and Spamer (2008) also presented with excessive anterior pelvic tilt, but fewer players showed no dysfunction with rotation and

extension ROM. Between 40.98% and 63.93% of players also present with leg length differences; ASIS, PSIS, Cleft and Rami asymmetry, an abnormal sacral rhythm, decreased lumbar flexion and an abnormal lumbar coronal view. 47.4% of the players from Serfontein and Spamer (2008) presented with a lumbar scoliosis and 68.4% of players presented with ASIS, PSIS, Rami, Cleft and sacral rhythm dysfunction, a further 34.2% presented with lumbar coronal dysfunction. Lumbar flexion was also similarly decreased in more in 63.16% of the Costa Papic Soccer Academy players.

The biomechanical profile of the neurodynamic area for club players shows the average club player to have a decreased prone knee bend test ROM, indicating L4 nerve root restriction. The results for the slump test were normal and 39.34% of players presented with a decreased Straight Leg Raise test ROM for the left side. Serfontein and Spamer (2008) showed similar results, although less dysfunction was present with the straight leg raise test. The combined total dysfunction score for the club players was 18.590 for the left side and 20.049 for the right side. Serfontein and Spamer (2008) showed total dysfunction scores of 19.605 for the left side and 20.737 for the right side.

The differences between the two sides could probably be attributed to the majority of players being right foot dominant and using the right foot more for passing and kicking activities, leading to specific patterns of muscle tightness, dysfunction and decreased ROM of certain joints. Unilateral muscle tightness could also lead to Sacro-iliac joint asymmetry, as is present in 52.46% of players.

5.2.3 Results and Discussion: Injury Epidemiology

The results of the epidemiological study on the Platinum Stars youth players for the 2008 season will now be discussed. The match, training and total injury rates per 1000 hours will be discussed and compared with existing research. The anatomical area of injury; severity of injuries; mechanism of injuries and type of injuries will also be discussed.

The U/17 team from Platinum Stars had 22 players in the group. They were involved in 2244 hours of training (68 training sessions) and 257 match hours (20 matches of 70 minutes each). During the course of the season, 19 injuries were recorded for the group. The nature of the injuries will be discussed in more detail later. Fifteen of the injuries were match injuries and 4 were training injuries. The match injury rate was 58.36/1000 match hours and a player incurred a match injury every 17.14 matches he played for the team. The injury rate for training sessions was 2.23 injuries/1000 training hours. The total injury rate for the U/17 group was 8.00 injuries/1000 hours.

The U/18 group consisted of 18 players, who were involved in 20 matches during the season. Each player was exposed to 30 hours of match play and 44 training sessions of an hour and a half each, giving training exposure of 1144 hours for the group. This training exposure is much lower than the U/17 group, due to Grade 12 exams influencing the regularity of training towards the end of the season. There were 12 recorded match injuries during the season and 13 training injuries. The injury rate for matches was 36.36/1000 match hours. This match rate indicates that a player could be expected to be

injured once every 27.50 matches he played for the team. The training injury rate was 11.59/1000 hours and the total injury rate was 17.22/1000 hours of exposure.

There were 21 players in the U/19 group of Platinum Stars. The team played 20 matches during the season, giving 330 hours of match exposure. There were 2646 hours of training exposure for the team during the season. Thirty five injuries were recorded during the season, with 15 of these being match injuries. The match injury rate for the U/19 group was 45.45 injuries/1000 match hours. An individual player could be expected to be injured once every 22 matches. The injury rate for training sessions was 7.56/1000 hours. Combining the match and training injury rates gave a combined injury rate of 11.76 injuries/1000 playing hours.

Table 5.13 shows a comparison between the groups from Platinum Stars and previous epidemiological research. The combined injury rates for the three age groups are also shown. The combined total injury rate was 11.51 injuries/1000 playing hours with the match injury rate being 45.80/1000 match hours and the training injury rate being 6.3/1000 training hours. Schmidt-Olsen *et al.* (1991) showed a total injury rate of 3.7/1000 hours for all players from 12 to 18 years, with 17 and 18 year olds having an injury rate of 4.0/1000 players hours. This rate is much lower than the rates recorded for the Platinum Stars Players at all age group levels and also low when compared to the other studies in the table. Junge *et al.* (2004) showed a total injury rate of 27.9 injuries/1000 hours. This is much higher than the rate of all the Platinum Stars player groups. The match injury rate of Junge *et al.* (2004) was recorded at 47.5 injuries/1000

match hours and is lower than that recorded for the U/17 group. It is similar to the match injury rate for the U/19 group from Platinum Stars and the rate for all the age groups combined. It is, however, higher than the rate of 36.36/1000 hours recorded for the U/18 group of Platinum Stars. The training injury rate from Junge *et al.* (2004) of 15.4/1000 training hours is higher than that recorded for the Platinum Stars players, with the U/18 training injury rate of 11.58/1000 hours being the closest. The U/17 training injury rate was lower than the training injury rate recorded by Le Gall *et al.* (2006) for 16 year old players (3.8/1000 hours).

It can be seen in the comparison that the Platinum Stars youth players had a very high match injury rate when compared to other studies, except Junge *et al.* (2004), which was similar. The training injury rate fell within the ranges indicated by the existing research, with the combined match and training injury rate for all players was lower than research by Junge *et al.* (2004), but higher than the other studies cited in Table 5.13. Generally, injury rates are influenced by the definition of an injury and the way the data is gathered. Data for this research was gathered in the method advocated by Fuller *et al.* (2006) in an effort to standardise soccer epidemiological research. Previous studies did not all conform to this accepted standard or were conducted before its inception, creating discrepancies and difficulty in comparisons. The current research study will be of great use for comparative purposes in future research on youth soccer injuries.

Table 5.13 Comparison of existing injury studies on youth soccer players and Platinum Stars youth players

	Platinum Stars U/17 (n=22)	Platinum Stars U/18 (n=18)	Platinum Stars U/19 (n=21)	Platinum Stars Combined	Junge <i>et al.</i> (2004)	Le Gall <i>et al.</i> (2006)	Schmidt-Olsen <i>et al.</i> (1991)	Emery & Meeuwisse (2006)
Injury Rate	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours
Total	8.00	17.21	11.76	11.51	27.9	5.2	3.7	4.45
Match	58.36	36.36	45.45	45.80	47.5	14.2	*	*
Training	2.23	11.59	7.56	6.30	15.4	3.8	*	*

* = Not available

Table 5.14 Comparison of injury area between existing injury studies and Platinum Stars youth players

	Platinum Stars U/17	Platinum Stars U/18	Platinum Stars U/19	Platinum Stars Combined	Price <i>et al.</i> (2004)	Deehan <i>et al.</i> (2007)	Junge <i>et al.</i> (2004)	Le Gall <i>et al.</i> (2006)	Schmidt-Olsen <i>et al.</i> (1991)
Area	% of total	% of total	% of total	% of total	% of total	% of total	% of total	% of total	% of total
Lower Limb	85	96	91.43	91.1	90	79	80.4	70.7	70
Foot	0	0	2.86	1.2	8	*	5.8	8.2	0.3
Ankle	25	28	25.71	26.5	19	*	17.2	17.8	23.1
Lower leg	25	16	5.74	13.9	10	*	16.1	5.2	10.9
Knee	15	12	28.60	20.2	18	*	15	15.3	26.0
Thigh	15	24	14.29	17.7	19	*	17	24.5	*
Hip and Groin	5	16	14.29	12.6	12	6.5	9.3	7.1	8.9
Overuse	0/ 40#	12/ 72#	11.43/ 57.14#	8.9/ 57#	34#	69 #	14.9/ 50 #	17.3	*

* = Not available # = Non Contact

Table 5.14 shows the anatomical area of injury for the Platinum Stars players and compares it to existing injury research. In all age groups, the lower limb predominantly had the highest injury occurrence, ranging between 85% (U/17) and 96% (U/18) with the combined total of the three age groups being 91.1%. Research by Price *et al.* (2004) showed a figure of 90% for the lower limb, with other studies ranging between 70% (Schmidt-Olsen *et al.*, 1991) and 80.4% (Junge *et al.*, 2004). Amongst the U/17 players, the ankle (25% of total) and lower leg (25% of total) were the individual areas with the highest percentage of injuries. Knee and thigh injuries amounted for 15% of injuries each. The U/18 group also had the highest number of ankle injuries (28% of total), followed by thigh injuries (24% of total) and lower leg and groin injuries (16% of total each). Price *et al.* (2004) showed similar findings with the ankle (19%) and thigh (19%) being most injured area.

The U/19 players from Platinum Stars FC presented with knee injuries as the most common area (28.6% of total), with ankles (25.71% of total), thigh and hip and groin injuries (14.29% of total) being the next most injured areas. Schmidt-Olsen *et al.* (1991) also showed the knee (26%) and the ankle (23.1%) to be the areas with most injuries. On the combined totals of all the age groups, the ankle was the most injured area (26.5% of total) followed by knee injuries (20.2% of total), thigh injuries (17.7% of total) and lower leg injuries (13.9% of total). Hip and groin injuries accounted for 12.6% of the total injuries. Junge *et al.* (2004) also had similar findings with the ankle (17.2%) being the most injured areas, although knee injuries were only ranked fourth, with 15% of the total injuries.

Table 5.15 shows the severity of injuries to Platinum Stars players. In the U/17 group, 25% of injuries were of 'zero day' severity, with no playtime lost. 40% of the injuries were documented as 'slight', indicating a one to three day absence from play. Another 25% of injuries were 'minor', with four to seven days of play missed. The other injuries were 'mild' (7-14 days off) or 'moderate' (14-28 days off) with 5% of injuries respectively. In the U/18 group, 32% of injuries were of 'zero day' severity. The majority of injuries were 'slight' (44%) with 12% being 'minor' and 12% 'mild'. In the U/19 group, 31.43% of injuries were 'zero day' injuries and 31.43% of injuries were classified as 'slight'. 14.29% of injuries were classified as 'minor' and 'mild' respectively. Another 5.72% of injuries were "moderate" and the remaining 2.86% of injuries were 'major' leading to an absence of more than 28 days from play. When the results for all the groups were combined, 30.3% of injuries were 'zero day'. The majority of injuries (38%) were 'slight'. 15.2% of injuries were 'minor', with another 11.4% of injuries being 'mild'. The remainder of the injuries were 'moderate' (3.8%) and 'major' (1.2%). From these results, it can be seen that 83.5% of injuries were relatively inconsequential, leading to absences of less than one week from play.

Table 5.15 Injury severity of Platinum Stars players

	U/17	U/18	U/19
Severity	% of total	% of total	% of total
Zero Day (0 days off)	25	32	31.43
Slight (1-3 days off)	40	44	31.43
Minor (4-7 days off)	25	12	14.29
Mild (7-14 days off)	5	12	14.29
Moderate (14-28 days off)	5	0	5.72
Major (more than 28 days off)	0	0	2.86

Table 5.16 shows the type of injuries as they occurred amongst the Platinum Stars players. In the U/17 group, Contusions were the most common type of injuries (45%) of total, with sprains

being the 2nd most common (35%). Le Gall *et al.* (2006) also showed contusions the most common type of injuries recorded (30.6%) with sprains and strains accounting for 16.7% and 15.3% of injuries respectively. The larger number of contusion injuries can be attributed to the high percentage of contact injuries incurred (60% of total). The U/18 and U/19 groups showed sprains and strains being the most common types of injuries, followed by contusions. Price *et al.* (2004) reported 31% of injuries being strains, 20% being sprains and 8% being contusions. Deehan *et al.* (2007) reported 37% of injuries as strains, 18% as sprains and only 5.8% as muscular contusions. Junge *et al.* (2004) reported 31.8% of injuries as strains, 20.3% as sprains and 28.4% as contusions. It can be seen from most of the previous research that sprains, strains and contusions amount for the largest percentage of injuries amongst youth players. This is also reflected in the combined totals for the Platinum Stars players, with sprains (34.2%), strains (31.6%) and contusions (22.8%) being the most common types of injuries.

The mechanism of injury in the U/17 group showed that 60% of injuries were contact injuries. The U/18 group had 72% of injuries as non-contact injuries and the U/19 group had 57.14% of injuries as non-contact injuries. The combined total of all age groups show 57% of injuries as non-contact injuries (Table 5.16). Emery and Meeuwisse (2006) showed similar figures with 54% of injuries being non-contact. Deehan *et al.* (2007) had a higher non-contact injury percentage of 69%, with Price *et al.* (2004) showing a much lower percentage of 34% as non contact injuries

Table 5.16 Mechanism of injury: Platinum Stars players

	Platinum Stars U/17	Platinum Stars U/18	Platinum Stars U/19	Platinum Stars Combined
Area	% of total	% of total	% of total	% of total
Contusion	45	16	14.29	22.8
Sprain	35	32	34.32	34.2
Strain	20	40	31.43	31.6
Overuse	0	12	11.43	8.9
Fracture	0	0	8.57	3.8
Non Contact	40	72	57.14	57
Contact	60	28	42.86	43

5.2.6 Summary of Injury Epidemiology

From the epidemiological study, it can be concluded that the Platinum stars players have injury rates (Training rate= 6.13/1000 training hours, Total rate=11.50/1000 player hours) that fall within rates that were previously recorded in research. The exception is the match injury rate (Match rate= 45.80/1000 match hours) which, although similar to research by Junge *et al.* (2004), is much higher than other research studies on youth soccer players by Price *et al.* (2004); Deehan *et al.* (2007); Le Gall *et al.* (2006); Schmidt-Olsen *et al.* (1991). The percentage of lower limb injuries (91.1% of total) is also similar to previous research. The ankle (26.5% of total), knee (20.2% of total) and thigh (17.7% of total) areas were the anatomical areas with the most injuries, which compares well with previous epidemiological research on youth players. 83.5% of injuries were relatively minor, with absences of less than one week. When compared to the previous research, the types of injuries similarly showed that sprains (34.2%), strains (31.6%) and contusions (22.8%) were the most common types of injuries amongst the players. 57% of the injuries were non contact injuries, a value which also falls within the ranges of previous research findings.

5.3 RESULTS AND DISCUSSION: SCHOOL PLAYERS

The results for the school players will now be discussed. The proprioception, balance and plyometric results will be discussed with comparisons between the different age groupings. Milner High School and St Conrad's College are of similar playing strength and compete in the same league. The U/16 groups from Milner and St Conrad's College will be compared with each other, as well as with the U/18 groups. The two U/18 groups, from Milner and St Conrad's College respectively, will also be compared to each other. The individual results for the two school U/16 teams are shown in Annexures D.1 to D.6. The individual results for the two U/18 teams are shown in Annexure D.7 to D.12. The biomechanical evaluation will be discussed next, also with comparisons between the different age groups. Lastly, the epidemiology of all injuries will be discussed and compared to existing research on youth injuries.

5.3.1 Proprioceptive and Plyometric Testing

Table 5.17 shows the age description, limb dominance, plyometric and proprioceptive results for the school players. The individual results for the two school U/16 teams are shown in Annexure D.1. Amongst the U/16 players, the only large effect practically significant difference between the two schools was for the age of the players, with the players from Milner being older. The other differences between the two U/16 teams were of small effect size for all the results, with the exception of the right single limb stance test. The majority of players in the U/16 group were right limb dominant (85.7%), with between 59.3% and 70.4% of the players failing the single limb stance balance test. The mean values for bilateral jumping height was 26.644cm, with a mean height of 14.626cm for the dominant side and 13.837cm for the non-dominant side.

The individual results for the two U/18 teams are shown in Annexure D.7. The comparative results for the U/18 players are shown in Table 5.17. In the results of the U/18 groups, there was one difference of high practical significance between the two U/18 teams, namely limb dominance ($d = 0.79$). The rest of the tests showed differences of small effect size, with the exception of age and Left single limb stance test. The mean value for limb dominance indicated right limb dominance in most players (90.5%). Between 55% and 60% of the players failed the single limb stance test, with mean values of 1.600 and 1.550 for the left and right sides respectively. The bilateral jump mean height was 29.775cm, with heights of 16.325cm for the dominant side and 15.855cm for the non dominant side.

In the comparison between the U/16 and U/18 groups, there was only one expected difference of large effect practical significance, namely age. The largest differences between the remaining tests were of the plyometric testing, where there were differences of medium effect size for bilateral jump height. Important to note is the extremely small differences between the plyometric ratios of the two age groups, with d -values below 0.09.

Table 5.17 Descriptive statistics and comparisons for age, limb dominance, proprioception and plyometric results of school soccer players

	Schools U/16				Schools U/18				Schools U/16 v U/18			
	Combined Mean		d Values		Combined Mean		d Values		Combined Mean		d Values	
AGE:	15.107		-1.54		17.524		-0.58		16.143		-3.48	
RIGHT LIMB DOMINANCE %	85.7		0.47		90.5		0.79		87.8		-0.15	
BALANCE	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
Single Limb Stance	1.593	1.704	-0.38	-0.62	1.600	1.550	-0.52	-0.36	1.596	1.638	-0.01	0.32
PLYOMETRICS												
Bilateral (cm)	26.644		-0.23		29.775		0.15		27.977		-0.52	
Dominant (cm)	14.626		-0.27		16.325		0.40		15.349		-0.43	
Non-Dominant (cm)	13.837		-0.39		15.855		-0.27		14.696		-0.49	
D+ND/Bil	1.068		-0.37		1.077		-0.10		1.072		-0.06	
D/Bil	0.547		-0.25		0.548		0.47		0.547		-0.01	
ND/Bil	0.521		-0.38		0.529		-0.51		0.525		-0.09	

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

5.3.2 Summary of Proprioceptive and Plyometric Testing

There were a total of 49 players from the U/16 and U/18 age groups at two schools taking part in the research study. The average age of the school players was 16.143 years. The majority of these players were right limb dominant (87.8%), with 59.6% and 63.8% of players failing a single limb stance test for left and right respectively. The performance in the left leg stance test was better than the right leg. The players tested by Serfontein and Spamer (2008) had a similar 86.8% right limb dominance, but showed that 78.9% and 73.6% of players failed the single limb stance test for left and right respectively. The mean bilateral jump height was 27.977cm, with a non-dominant leg jump height of 14.696cm and a dominant leg jump height of 15.349cm. Even less talented school soccer players tested by Badenhorst (1998) showed better bilateral jump heights of 32.2cm and U/14 schoolboy rugby players tested by Serfontein (2006) also performed better with bilateral jump height of 32.41cm. With 87.8% of players being right limb dominant the non-dominant leg of school players (Left side) performed better with balance activities. If the level of skill is taken into account, school players play more with their dominant legs, while club players tend to be more ambidextrous in normal play. This higher level of right (dominant) leg kicking in school players leads to the left leg being in a supportive stance more often, probably leading to increased balance.

5.3.3 Biomechanical Evaluation

The results of the biomechanical evaluation will now be discussed. These results are divided into 5 sections. These are: the foot and lower leg section; the knee section; the upper leg and hip section; the lumbo-pelvic area and the neurodynamic section. Sections

also contain a combined dysfunction score for the specific area. This combined dysfunction score is an indication of the total dysfunction for a particular area and is combined out of dysfunction scores from the individual tests. There is also a Total combined dysfunction score given, which comprises of the individual combined dysfunction scores.

Table 5.18 shows the results for the school players for the lower leg and ankle portion of the biomechanical evaluation. The individual results for the two U/16 teams appear in Annexure D.2 and the individual results for the two U/18 teams are shown in Annexure D.8. In the comparison between the two U/16 teams from Milner and St Conrad's, there were large effect practically significant differences for the Achilles tendon suppleness test; the pronation components of the rear foot standing and rear foot lying tests; the toe positional test and the left leg previous injury history. The combined mean values of the two schools indicate a mean value close to dysfunction for the toe positional test (mean = 1.893). The mean values of the transverse arch test; low arch component of the longitudinal arch test, the pronation components of the rear foot standing and rear foot lying tests and the hypomobility component of the mid-foot mobility test indicate that between 50.0% and 60.7% of the players presented with dysfunction in these areas. The remainder of the tests reflected mean values close to normal values with little dysfunction. The mean values for the combined dysfunction score were 4.429 for the left side and 4.357 for the right side.

In the comparison between the results for the two U/18 groups (Table 5.17), there was only one difference of high practical significance, namely the pronation component for the rear foot lying test. The mean values of the toe dysfunction test in the U/18 group indicate dysfunction with this test in most players (mean = 1.952). The mean values of the transverse arch test, low arch component of the longitudinal test; the pronation components of the rear foot standing and lying tests and the hypomobility component of the mid-foot mobility test indicates between 52.4% and 81.0% of the players had dysfunctional results in these areas. The remainder of the tests had mean values close to normal, with minimal dysfunction present.

In the comparison between the U/16 and U/18 groups (Table 5.18), there were no differences of high practical significance between the two age groups. The combined results of the U/16 and U/18 groups show a mean value for the toe positional test suggesting that most of the players had a dysfunctional result for this test (mean = 1.918). The mean results for the low arch component of the transverse arch test, foot longitudinal arch test; the pronation component of the rear foot lying and standing test and the hypomobility component of the mid-foot mobility test indicate that between 51.0% and 69.4% of the players presented with dysfunctional results in these tests. The remainder of the tests show mean values indicating normal results for these tests.

Table 5.18 Descriptive statistics and comparisons for lower leg biomechanical results of school soccer players

	School U/16				School U/18				School U/16 vs U/18			
	Combined Mean		d Values		Combined Mean		d Values		Combined Mean		d Values	
FOOT AND LOWER LEG	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
ACHILLES TENDON SUPPLENESS TEST	1.071	1.071	0.76	0.76	1.143	1.143	0.56	0.56	1.102	1.102	-0.23	-0.23
FOOT LONGITUDINAL TEST												
High Arch	1.036	1.036	0.51	0.51	1.000	1.000	0.00	0.00	1.020	1.020	0.38	0.55
Low Arch	1.571	1.536	0.12	0.27	1.667	1.667	0.14	0.14	1.612	1.592	-0.19	-0.26
FORE FOOT	1.500	1.500	0.42	0.42	1.190	1.190	0.34	0.34	1.367	1.367	0.68	0.68
REAR FOOT STANDING TEST												
Pronation	1.607	1.607	-1.53	-1.53	1.762	1.762	-0.64	-0.64	1.673	1.673	-0.33	-0.34
Supination	1.000	1.000	0.00	0.00	1.000	1.000	0.00	0.00	1.000	1.000	0.00	0.00
REAR FOOT LYING TEST												
Pronation	1.607	1.607	-1.53	-1.53	1.810	1.810	-0.89	-0.89	1.694	1.694	-0.45	-0.45
Supination	1.000	1.000	0.00	0.00	1.000	1.000	0.00	0.00	1.000	1.000	0.00	0.00
TRANSVERSE ARCH	1.500	1.500	0.14	0.14	1.524	1.524	0.57	0.57	1.510	1.510	-0.05	-0.05
MID-FOOT MOBILITY TEST												
Hypomobility	1.571	1.536	0.12	0.27	1.714	1.714	0.00	0.00	1.633	1.612	-0.30	-0.37
Hypermobility	1.036	1.036	0.51	0.51	1.000	1.000	0.00	0.00	1.020	1.020	0.38	0.38
TOES	1.893	1.893	-0.98	-0.98	1.952	1.952	0.53	0.53	1.918	1.918	-0.22	-0.22
PREVIOUS INJURY	1.071	1.071	-0.81	-0.04	1.095	1.095	0.22	0.22	1.082	1.082	-0.08	-0.08
DYSFUNCTION SCORE /10	4.429	4.357	-0.53	-0.32	4.810	4.810	0.24	0.24	4.592	4.551	-0.27	-0.33

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Table 5.19 illustrates the results for the knee area of the biomechanical evaluation for the players from Milner and St Conrad's college. The individual results for the two U/16 teams are shown in Annexure D.3 and the individual results for the two U/18 teams are shown in Annexure D.9. In the U/16 group there was a high practically significant difference for the VMO:VL visual comparison test. The rest of the tests showed difference with less than small effect size, with the exception of left previous injury ($d = 0.55$) and right leg dysfunction score ($d = 0.27$). The mean values of the test scores indicate minimal dysfunction and normal values for this area, with only the knee height test indicating that 57.1% of the players presented with knee height differences. The mean values for the combined dysfunction score was 1.607 for the left side and 1.679 for the right side. This score is calculated out of 8, and indicates a very low level of dysfunction in the knee area.

The results for the U/18 groups (Table 5.19) show only one high practically significant difference between the two school groups, namely the previous injury history. The rest of the test showed differences of medium effect size or less. The results of the quadriceps component of the Thomas test (mean=1.524) and the knee height test (mean = 1.571) indicate between 52.4% and 57.14% of players presented with dysfunction in these two areas. The rest of the tests had mean values indicative of minimal or no presence of dysfunction. The mean values for the combined dysfunction scores were 1.667 for the left side and 1.619 for the right side.

The combined results for the U/16 and U/18 school players for the knee area are also shown in Table 5.19. There were no high practically significant differences between the age groups for the knee area. The rest of the tests showed differences of medium effect size or even less. The results of the two groups show that 40.82% of the players presented with dysfunction in quadriceps length as tested with the Thomas test (mean = 1.408) and 57.1% of the players also presented with knee height differences. The rest of the tests showed mean values of close to “1”, indicating no dysfunction present. The dysfunction score is calculated out of a maximum of 8 and the mean values of 1.633 for left and 1.653 right sides indicate very little dysfunction in the groups for the knee area.

Table 5.19 Descriptive statistics and comparisons for knee area biomechanical results of school soccer players

	Schools U/16				Schools U/18				Schools U/16 v U/18			
	Combined Mean		d Values		Combined Mean		d Values		Combined Mean		d Values	
KNEE	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
THOMAS TEST: QUADS	1.321	1.321	0.05	0.05	1.524	1.524	0.57	0.57	1.408	1.408	-0.41	-0.41
KNEE Q-ANGLE	1.107	1.107	0.18	0.18	1.000	1.000	0.00	0.00	1.061	1.061	0.68	0.68
PATELLA SQUINT	1.107	1.107	0.18	0.18	1.000	1.000	0.00	0.00	1.061	1.061	0.68	0.68
PATELLA TILT	1.393	1.393	0.03	0.03	1.333	1.333	0.29	0.29	1.367	1.367	0.12	0.12
KNEE HEIGHT	1.571	1.571	0.12	0.12	1.571	1.571	0.42	0.42	1.571	1.571	0.00	0.00
VMO	1.071	1.071	0.76	0.76	1.095	1.048	0.22	-0.53	1.082	1.061	-0.09	0.07
PREVIOUS INJURY	1.036	1.107	-0.55	0.18	1.143	1.143	-1.00	-1.00	1.082	1.122	-0.39	-0.11
DYSFUNCTION SCORE /8	1.607	1.679	0.19	0.27	1.667	1.619	0.51	0.39	1.633	1.653	-0.05	0.05

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Table 5.20 shows the results for the hip area of the biomechanical evaluation for the school players. Important to remember, is that most tests in this area have a maximum value of “3”, instead of “2” as in most other tests. The individual results for the two U/16 teams are shown in Annexure D.4. There were only high practically significant differences for the ITB tests for the left and right side between the two U/16 groups. The mean results for Hip external rotation (Mean = 1.821 Left and Right) and Gluteal muscle length tests (Mean = 1.929 Left and Right) showed values close to dysfunctional. The mean results for Hip internal rotation and previous injuries were close to normal (normal = 1). The mean values for the combined dysfunction score for the U/16 groups were 2.893 for the left side and 2.929 for the right side. This score was calculated out of a maximum of 13.

The combined results for the U/18 school groups are also reflected in Table 5.20, with the individual results for the two teams being shown in Annexure D.10. Amongst the U/18 groups, there were high practically significant differences between the two groups for the ITB tests, Adductor length test, Hip internal rotation test and the combined dysfunction score. The large amount of differences between these two groups could probably be ascribed to the small number of subjects in the St Conrad's U/18 team that were tested ($n=7$), and the uniformity of their test results. The mean value of the Hip external rotation tests (mean = 1.857 Left and Right) and the Gluteal muscle length tests (mean = 1.952 Left and Right) reflected dysfunctional values, while the mean values for Hip internal rotation and previous injury were close to normal (normal = 1). The mean combined dysfunction score for this area was 2.762 for the left side and 2.810 for the right side.

In the comparison between the U/16 and U/18 school groups, there were only high practically significant differences for previous injury history, which can be ascribed to the U/16 group having a shorter history of exposure to play. The rest of the differences between the two age groups were of small effect size or less. The mean values of Hip external rotation (mean = 1.837 Left and Right) and Gluteal muscle length tests (mean = 1.939 Left and Right) showed mean values close to dysfunctional, with Hip internal rotation and previous injury showing mean values of close to normal. The combined dysfunction scores had mean values of 2.837 for the left side and 2.878 for the right side with d-values of 0.10 and 0.08 for left and right respectively, indicating uniformity in the results of the two age groups.

Table 5.20 Descriptive statistics and comparisons for hip area biomechanical results of school soccer players

	Schools U/16				Schools U/18				Schools U/16 vs U/18			
	Combined Mean		d Values		Combined Mean		d Values		Combined Mean		d Values	
HIP	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
ITB	1.429	1.464	1.77	1.38	1.286	1.381	1.69	1.09	1.367	1.429	0.30	0.17
ILIOPSOAS	1.393	1.393	0.54	0.54	1.238	1.238	0.16	0.16	1.327	1.327	0.31	0.31
GLUTEAL MUSCLES	1.929	1.929	0.40	0.02	1.952	1.952	0.30	0.30	1.939	1.939	-0.06	-0.06
ADDUCTOR LENGTH	1.286		-0.40		1.191		0.89		1.245		0.22	
HIP INTERNAL ROTATION	1.036	1.036	0.51	0.51	1.048	1.048	0.75	0.75	1.041	1.041	-0.06	-0.06
HIP EXTERNAL ROTATION	1.821	1.821	-0.10	-0.35	1.857	1.857	0.00	0.00	1.837	1.837	-0.07	-0.07
PREVIOUS INJURY	1.000	1.000	0.00	0.00	1.190	1.143	-0.18	0.00	1.082	1.061	-0.95	-0.80
DYSFUNCTION SCORE /13	2.893	2.929	0.72	0.40	2.762	2.810	0.93	0.87	2.837	2.878	0.10	0.08

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Table 5.21 shows the results for the biomechanical evaluation of the Lumbo-pelvic area for the school players. In the U/16 age group, there were only differences of high practical significance for the lumbar flexion test and rotational test to the left and right. The rest of the tests showed differences of small effect size or less, with the exception of Lumbar extension ($d = 0.51$) and Pelvis bilateral position ($d = 0.55$). The Pelvis bilateral positional test (mean = 1.964) and the Lumbar coronal view tests (mean = 1.929) were the only tests with mean values close to dysfunctional results. Important to note is also the similar values for the ASIS, PSIS, Rami, Cleft, Pelvic rhythm and leg length, which lend further weight to the possibility of combining these tests into a single SIJ dysfunction score. The combined Lumbo-pelvic dysfunction score had mean values of 4.964 for both left and right side and was calculated out of a maximum of 21. The individual results for the two U/16 teams for this area can be seen in Annexure D.5.

The comparative results of the U/18 groups (Table 5.21) shows high practically significant differences between the two U/18 groups for the Lumbar extension test as well as the side flexion tests. There were also differences of medium effect size for Leg length, ASIS, PSIS, Rami, Cleft, Sacral Rhythm, Thoraco Lumbar Fascia and Lumbar Flexion. With the exception of Thoraco Lumbar Fascia and Lumbar flexion tests, the previously named tests, once again, show remarkable similarity in values. The Pelvis Bilateral positional test (mean = 2.000) and the Lumbar coronal test (mean = 2.000) showed dysfunctional mean values. The Thoraco Lumbar Fascia test results (mean = 1.476 Left and Right) indicate that 47.6% of players presented with dysfunction in this test. The combined dysfunction score for the Lumbo-pelvic area had mean values of 5.381 for both

left and right sides. The individual results for the two U/18 teams can be seen in Annexure D.11.

In the comparison between the U/16 and U/18 groups for the Lumbo-pelvic area, there were no high practically significant differences for any tests. The rest of the tests showed differences of medium effect size or less. The mean values for the Pelvis Bilateral positional test (mean = 1.980) and the Lumbar Coronal tests (mean 1.959) indicated dysfunction in between 95.9% and 97.96% of players for these two tests. The results of the Rotation (mean = 1.041 Left and Right) and Extension tests (mean = 1.122) indicate that between 4.08% and 12.24% of players exhibited dysfunction in these tests. The results of the Flexion test (mean = 1.531) indicate that 48.98% of players presented with decreased lumbar flexion. The mean values for the combined lumbar dysfunction scores was 5.143 for both left and right side, with a maximal dysfunction score of 21 possible for this area.

Table 5.21 Descriptive statistics and comparisons for lumbo-pelvic area biomechanical results of school soccer players

	Schools U/16				Schools U/18				Schools U/16 vs U/18			
	Combined Mean		d Values		Combined Mean		d Values		Combined Mean		d Values	
LUMBO PELVIC AREA	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
LEG LENGTH	1.286		-0.09		1.381		-0.69		1.327		-0.18	
ASIS	1.250		0.08		1.333		-0.64		1.286		-0.18	
PSIS	1.250		0.08		1.333		-0.64		1.286		-0.18	
RAMI	1.250		0.08		1.333		-0.64		1.286		-0.18	
CLEFT	1.250		0.08		1.333		-0.64		1.286		-0.18	
PELVIS BILATERAL POSITION	1.964		0.55		2.000		0.00		1.980		-0.38	
THORACO LUMBAR FASCIA	1.464	1.464	0.29	0.29	1.476	1.476	0.72	0.72	1.469	1.469	-0.02	-0.02
SACRUM RHYTHM	1.250		0.10		1.333		-0.64		1.286		-0.18	
EXTENSION	1.179		0.51		1.048		0.75		1.122		0.43	
FLEXION	1.536		0.80		1.524		0.58		1.531		0.02	
ROTATION	1.071	1.071	0.76	0.76	1.000	1.000	0.00	0.00	1.041	1.041	0.54	0.54
SIDE FLEXION	1.321	1.321	0.36	0.36	1.238	1.238	1.25	1.25	1.286	1.286	0.18	0.18
LUMBAR CORONAL	1.929		0.04		2.000		0.00		1.959		-0.54	
LUMBAR SAGGITAL	1.321		0.05		1.095		0.22		1.224		0.58	
DYSFUNCTION SCORE /21	4.964	4.964	0.41	0.41	5.381	5.381	-0.18	-0.18	5.143	5.143	-0.13	-0.13

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Table 5.22 shows the results of the neurodynamic testing for the schoolboy players. It also contains the results of the total combined dysfunction score for all areas. The individual results for the two U/16 teams can be seen in Annexure D.6. In the comparison between the two U/16 teams, there were no high practically significant differences. The other tests and the Total dysfunction score had differences of medium effect size of less. The results of the Straight Leg Raise tests (mean = 1.464 Left and Right) indicate that 46.43% of players presented with dysfunction in this test. The mean value for the combined neural dysfunction score had a value close to normal (normal = 1), indicating minimal dysfunction in this area. The mean values for the Total combined dysfunction score were 14.929 for the left side and 14.964 for the right side. This score was calculated out of a maximum of 58.

In the comparison between the two U/18 groups, there were high practically significant differences for the Prone Knee Bend and Slump tests as well as the combined neural dysfunction score. The large differences could probably be attributed to the small sample size of the St Conrad's U/18 team (n=7) skewing the results, as five players from St Conrad showed dysfunction and six players from Milner showed dysfunction. The results of the Straight leg raise test (1.524 Left and Right) indicate that 52.38% of the players presented with decreased Straight Leg Raise ROM. The Total Combined dysfunction scores for the U/18 players were 15.619 for the left side and right sides. The individual results for the two U/18 teams are shown in Annexure D.12.

In the comparison between the U/16 and U/18 groups (Table 5.22), there were only differences of small effect size or less between the two groups, indicating homogenous results. The results of the Straight leg raise tests (mean = 1.490 Left and Right) showed that 48.98% of players presented with a decreased Straight leg raise. The combined neural dysfunction score mean values of 1.020 indicate that 51% of players exhibited some level of dysfunction in the neural area. The Total combined dysfunction score had mean values of 15.224 for the left side and 15.245 for the right side. The score is calculated out of 58, indicating approximately 26% dysfunction present in the players.

Table 5.22 Descriptive statistics and comparisons for neurodynamic area biomechanical results of school soccer players

	Schools U/16				Schools U/18				Schools U/16 vs U/18			
	Combined Mean		d Values		Combined Mean		d Values		Combined Mean		d Values	
NEURODYNAMICS	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right	Left	Right
STRAIGHT LEG RAISE	1.464	1.464	0.59	0.59	1.524	1.524	0.57	0.57	1.490	1.490	-0.12	-0.12
PRONE KNEE BEND	1.214	1.214	0.27	0.27	1.190	1.190	2.16	2.16	1.204	1.204	0.06	0.06
SLUMP	1.357	1.357	0.19	0.19	1.238	1.238	2.92	2.92	1.306	1.306	0.26	0.26
DYSFUNCTION SCORE /6	1.036	1.036	0.43	0.43	1.000	1.000	2.00	2.00	1.020	1.020	0.03	0.03
TOTAL DYSFUNCTION SCORE /58	14.929	14.964	0.41	0.40	15.619	15.619	0.67	0.63	15.224	15.245	-0.14	-0.13

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

5.3.4 Summary of Biomechanical Evaluation

A lower leg and foot profile for school players shows them having dysfunctional toe position, normal Achilles tendon suppleness; a normal or low foot arch; normal forefoot position; a normal or pronated rear foot; a normal or hypomobile mid-foot joint and a normal or dysfunctional transverse arch. Players, also, would probably not have had any previous injuries. The foot profile appears similar to club players, with flat arches, pronated rear feet and decreased mid-foot mobility occurring together. Club players evaluated by Serfontein and Spamer (2008) presented slightly differently, with decreased Achilles tendon suppleness, only 60% to 63% of players presenting with toe dysfunction and less rear foot pronation being present. The rest of the foot and lower leg presented similarly.

The biomechanical profile of the knee area for school players is described as follows: Players have normal Q-angles, no patella squinting, normal patella tilting, normal visual VMO:VL ratio and no history of previous injury to the area. There is also some tightness of the quadriceps muscles and the possibility of a knee height difference in 57.1% of players. Club players from Serfontein and Spamer (2008) showed similar biomechanical patterns, with the exception of the knee height difference which was only present in 21% of players.

The schoolboy player biomechanical profile for the hip area could be described as a player with shortened Hip external rotators and reduced Gluteal muscle length. Hip internal rotation showed normal ROM and no previous injuries were recorded. Between

24.5% and 42.9% of players exhibit shortened ITB, Iliopsoas and Adductor muscles. Amongst club players from the Costa Papic Soccer Academy (Serfontein and Spamer, 2008) there was also shortened hip external rotation, normal hip internal rotation ROM and no previous injury. Between 44.74% and 78.95% of Costa Papic Soccer Academy players presented with Gluteal muscle length, decreases ITB length and shortened adductor muscles.

The Lumbo-pelvic profile for school players, is described as follows: players present with an excessive anterior pelvic tilt and an excessive lumbar lordosis, as is indicated by the Lumbar coronal view. Lumbar rotation and Extension ROM are normal and 49% of players will present with decreased lumbar flexion. Between 22.4% and 29.2% of players will also present with SIJ dysfunction (Leg length, ASIS, PSIS, Rami, Cleft and Sacral rhythm combined) and abnormal Lumbar sagittal view (scoliosis). The SIJ dysfunction score was created based on the similarity of the values for the Leg length, ASIS, PSIS, Rami, Cleft and Sacral rhythm tests in both schoolboy and club players. When compared to a similar evaluation of Serfontein and Spamer (2008) on club players, the club players also presented with an increased anterior pelvic tilt, although it was not associated with an increased lumbar lordosis. SIJ dysfunction in the the Costa Papic Soccer Academy club players was present in 68% of the population. Lumbar extension deficits and decreased rotation was also more common amongst the Costa Papic Soccer Academy club players than the school players.

In the biomechanical evaluation of schoolboy players for the neurodynamic area, 49% of players exhibited decreased Straight leg raise values. Between 20.4% and 30.6% of players also presented with dysfunctional Prone knee bend and Slump neurodynamic tests. The Total combined dysfunction score had mean values of 15.22 for the left side and 15.25 for the right side, indicating similar levels of dysfunction for both sides. The Costa Papic Soccer Academy players presented with less dysfunction of the Straight leg raise test and slump test. The Prone knee bend test, however, had a dysfunctional mean value (2.053 left and 2.158 right), showing more dysfunction than the school players. The total dysfunction score was also higher than the school players with 19.605 for the left side and 20.737 for the right side (Serfontein and Spamer, 2008).

5.3.5 Injury Epidemiology

The results of the injury epidemiology study on the school players will now be reviewed. The results of the match, training and total injury rates per 1000 hours will be discussed and will also be compared to existing research. There will also be a discussion of the anatomical area of injury; severity of injuries; mechanism of injuries and type of injuries that were incurred by the school players during the season.

Table 5.23 shows the injury epidemiology the results for the school players, giving the training, match and total injury rates per 1000 playing hours. The twenty-eight U/16 players were involved in 242 match exposure hours and 390 hours of training. There were 3 match injuries and 9 training injuries during the season, giving a combined total of 12 injuries. These injuries and exposure hours resulted in a match injury rate of 12.397/1000 match hours; a training injury rate of 23.077/1000 training hours and a combined total

injury rate of 18.987/1000 hours. The match injury rate indicates that an individual player would get injured every 80.66 matches.

The U/18 school groups consisted of 21 players, involved in 242 match exposure hours and 406 training exposure hours. There were 7 match injuries and 2 training injuries during the season. The injuries resulted in a match injury rate of 28.926/1000 match hours; a training injury rate of 4.926/1000 training hours and a total injury rate of 13.888/1000 hours. An individual player could be expected to incur a match injury every 34.57 matches.

Table 5.23 compares the school injury rates to the rates from existing research on youth soccer players. The total injury rate for the school players was 16.41/1000 playing hours. This is lower than the reported research by Junge *et al.* (2004), which showed a total injury rate of 27.9/1000 hours. It is also higher than the rates reported by Le Gall *et al.* (2006), Schmidt-Olsen *et al.* (1991) and Emery and Meeuwisse (2006). The match injury rate for all school players combined was 20.66/1000 match hours. This is lower than the rate of 47.5/1000 match hours reported by Junge *et al.* (2004), but higher than the rate of 14.2/1000 hours reported by Le Gall *et al.* (2006). The combined training injury rate for the school players was 13.82/1000 training hours. This is only slightly lower than research by Junge *et al.* (2004), but still higher than the rate of 3.8/1000 training hours reported by Le Gall *et al.* (2006). The school injury rates fall within the ranges reported by previous research, although only research by Junge *et al.* (2004) showed higher injury rates.

Table 5.24 shows the anatomical area of injury for the school players and compares it to previous injury studies on youth soccer players. The lower limb accounted for between 75% and 77.78% for the two school age groups which is lower than the percentages reported by Price *et al.* (2004), Deehan *et al.* (2007) and Junge *et al.* (2004), but higher than the percentages reported by Le Gall *et al.* (2006) and Schmidt-Olsen *et al.* (1991). The percentages from these previous research studies range between 70% and 90%. In the U/16 group, the lower leg, knee and thigh areas were the most injured areas. Junge *et al.* (2004) also showed high percentages of injury for the knee, thigh and lower leg injury, although the research showed the ankle to be the most injured area. In the U/18 group, the ankle was the area with the highest number of injuries, followed by the knee and lower leg areas. This is similar to the findings of Schmidt-Olsen *et al.* (1991), which also showed the ankle (23.1%), knee (26%) and lower leg (10.9%) to be the most injured areas. The combined results for the U/16 and U/18 groups also show a similar trend, with the ankle (23.81% of total) being the area with the most injuries, followed by the knee (19.05%) and lower leg (19.05%) areas. The recorded overuse injuries for the combined age groups had a similar percentage than the 17.3% recorded by Le Gall *et al.* (2006), while the non-contact injuries had a similar percentage to the 34% recorded by Price *et al.* (2004).

Table 5.23 Comparison of existing injury studies on youth soccer players and school players

	Schools U/16	Schools U/18	Schools Combined	Junge <i>et al.</i> (2004)	Le Gall <i>et al.</i> (2006)	Schmidt- Olsen <i>et al.</i> (1991)	Emery & Meeuwisse (2006)
Injury Rate	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours	/1000 hours
Total	18.9	13.89	16.41	27.9	5.2	3.7	4.45
Match	12.40	28.93	20.66	47.5	14.2	*	*
Training	23.08	4.93	13.82	15.4	3.8	*	*

* = Not available

Table 5.24 Comparison of injury area between existing injury studies and school players

	Schools U/16	Schools U/18	Schools Combined	Price <i>et al.</i> (2004)	Deehan <i>et al.</i> (2007)	Junge <i>et al.</i> (2004)	Le Gall <i>et al.</i> (2006)	Schmidt- Olsen <i>et al.</i> (1991)
Area	% of total	% of total	% of total	% of total	% of total	% of total	% of total	% of total
Lower Limb	75.00	77.78	76.19	90	79	80.4	70.7	70
Ankle	8.33	44.44	23.81	19	*	17.2	17.8	23.1
Lower leg	25.00	11.11	19.05	10	*	16.1	5.2	10.9
Knee	16.66	22.22	19.05	18	*	15	15.3	26.0
Thigh	16.66	0	9.52	19	*	17	24.5	*
Hip and Groin	8.33	0	4.76	12	6.5	9.3	7.1	8.9
Overuse	16.66/ 33.33#	22.22/ 44.44#	19.05/ 38.10#	34#	69 #	14.9/ 50 #	17.3	*

* = Not available # = Non Contact

Table 5.25 shows the type of injuries incurred by the school players. Contusions were the most common injuries in all the age groups, with sprains being the second most common in the U/18 group and strains being the second most common in the U/16 group. The combined total for the two groups also showed contusions (47.62% of total) to be the most common types of injuries, followed by sprains (19.05%) and overuse injuries (19.05%). Le Gall *et al.* (2006) also showed that contusions were the most common type of injury (30.6% of total injuries) with sprains and strains accounting for 16.7% and 15.3% of injuries respectively. Other studies, however, show that strains account for high percentages of all injuries, with contusions having a smaller contribution. Price *et al.* (2004) reported 31% of injuries being strains, 20% being sprains and 8% being contusions. Deehan *et al.* (2007) reported 37% of injuries as strains, 18% as sprains and only 5.8% as muscular contusions. Junge *et al.* (2004) reported 31.8% of injuries as strains, 20.3% as sprains and 28.4% as contusions.

In the school players, 38.10% of injuries were non-contact injuries, with 61.9% of injuries being contact type injuries. Emery and Meeuwisse (2006) showed much higher figures, with 54% of injuries being non-contact. Deehan *et al.* (2007) also had nearly double the non-contact injury percentage with 69%. Price *et al.* (2004) reported a more similar percentage with 34% as non contact injuries.

Table 5.25 Mechanism of injury: School players

	Schools U/16	Schools U/18	Schools Combined
Area	% of total	% of total	% of total
Contusion	50	44.44	47.62
Sprain	8.33	33.33	19.05
Strain	25.00	0	14.29
Overuse	16.66	22.22	19.05
Non Contact	33.33	44.44	38.10
Contact	66.67	55.56	61.90

When the severity of injuries is examined for school players (Table 5.26), the U/16 group showed 58.33% of injuries as 'zero day' injuries. 25% of injuries were slight, with 8.33% of injuries categorised as 'minor' or 'moderate' respectively. The U/18 group showed 55.56% of injuries as 'zero day' injuries and 22.22% 'minor'. 'Slight' and 'mild' injuries accounted for 11.11% respectively. When the two groups are combined 57.14% of injuries are reported as 'zero day', with 19.05% being slight. A further 14.29% of injuries were classified as 'minor' with the remaining injuries being either 'mild' (4.76%) or 'moderate' (4.76%). From these results, it can be deduced that the injuries to the school players were not very severe, with more than half of injuries not leading to any time lost from play and 90.48% of injuries leading to less than a week of missed play.

Table 5.26 Injury severity of school players

	Schools U/16	Schools U/18	Schools Combined
Severity	% of total	% of total	% of total
Zero Day (0 days off)	58.33	55.56	57.14
Slight (1-3 days off)	25	11.11	19.05
Minor (4-7 days off)	8.33	22.22	14.29
Mild (7-14 days off)	0	11.11	4.76
Moderate (14-28 days off)	8.33	0	4.76
Major (more than 28 days off)	0	0	0

5.3.6 Summary of Injury Epidemiology

School players presented with injury rates of 20.66 injuries/1000 match hours, 13.82 injuries/1000 training hours and a combined total of 16.41 injuries/1000 playing hours. These rates are higher than those of club players, with the exception of the match injury rate. The percentage of lower limb injuries was 76.19% of the total injuries. The ankle, knee and lower leg were the areas with the highest percentage of injuries, with 23.81%, 19.05% and 19.05% of the total injuries respectively. Contusions (47.62% of total), sprains (19.05% of total) and overuse (19.05% of total) were the types of injuries with the highest occurrence rate. The high levels of contusion injuries and injuries to the lower leg and ankle areas could indicate that there was not enough use of protective equipment for the shin area and these injuries could possibly be avoided by the use of shin guards by all players. Only 38.1% of injuries were non-contact injuries with 61.9% of injuries being contact injuries. High contact injury rates are usually associated with high percentages of contusion injuries. The lower percentage of non-contact injuries correlate well with the biomechanical evaluation results, where school players presented with a more normal profile than club players. This has significance for the creation of a prediction model for these non contact injuries. 90.48% of injuries incurred by school players had a severity that led to less than a week absence from play. 57.14% of these injuries resulted in no play missed.

5.4 COMPARISON: SCHOOL AND CLUB PLAYERS

The results from the school and club players will now be compared to each other. This is to determine differences and similarities between the two player groups. All school

players are combined into one group and all club players are combined into one group. These results are a combination of the results of all players, and not a combination of the means of different age groups. The proprioception, plyometric results, biomechanical evaluation and injury epidemiology will be discussed when comparing the two player groups and mean values for combined results will also be given. This will then give a profile of the South African youth soccer player. This profile forms the basis of the creation of a prediction model, as the biomechanical, proprioception and plyometric results are compared with injuries to create a prediction model. "Youth" players are all club and school players combined.

5.4.1 Proprioceptive and Plyometric Testing

Table 5.27 shows the results for the proprioceptive and plyometric testing of the school and club players. There were practically significant differences between school and club players for all plyometric tests as well as the D+ND/Bil, D/Bil and ND/Bil ratios. The club players outperformed their school counterparts by a large margin of 10.25cm in the bilateral jump and nearly 14cm in the unilateral jumps. These large differences in unilateral jump height also led to the high practically significant differences in the D+ND/Bil, D/Bil and ND/Bil ratios. The differences for limb dominance and the single limb stance test were of small effect size or less, showing that both groups were predominantly right leg dominant (83.6%) and that the proprioception for all players was poor, with 65.7% of players failing the single limb stance test. This poor proprioception could be ascribed to the adolescent age of the players and the increased growth rate in teenagers leading to decreased proprioception.

Table 5.27 Comparison of data for school and club soccer players for age, limb dominance, proprioception and plyometric tests

N	School Players				Club Players				School vs Club Players			
	49				61				110			
	Mean		Std Dev		Mean		Std Dev		Combined Mean		d Values	
AGE:	16.143		1.40		16.967		1.32		16.600		-0.61	
RIGHT LIMB DOMINANCE %	1.878		0.33		1.803		0.40		1.836		0.21	
BALANCE	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	R Mean	d Values L	d Values R
Single Limb Stance	1.596	0.50	1.638	0.49	1.705	0.46	1.672	0.47	1.657	1.657	-0.23	-0.07
PLYOMETRICS	Mean		Std Dev		Mean		Std Dev		Mean			
Bilateral (cm)	27.977		6.12		38.230		8.14		33.768		-1.44	
Dominant (cm)	15.349		4.00		28.180		6.82		22.596		-2.37	
Non-Dominant (cm)	14.696		4.13		28.803		7.07		22.664		-2.52	
D+ND/Bil	1.072		0.14		1.496		0.19		1.311		-2.57	
D/Bil	0.574		0.08		0.740		0.11		0.656		-1.75	
ND/Bil	0.525		0.09		0.755		0.11		0.655		-2.30	

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

5.4.2 Summary of Proprioceptive and Plyometric Testing

There were 110 youth players involved in the research study from seven teams from four different age groups. There were two groups of U/16 players, an U/17 group, three U/18 groups and an U/19 group. The players were involved in 7974 hours of exposure to training and match play during the seasons in which they were monitored. The average age of the players was 16.6 years. The majority of players were right limb dominant (83.6%) and 65.7% of players failed a single limb stance test. The mean jump height for both legs combined was 33.77cm, with mean heights of 22.60cm for dominant leg jump and 22.66cm for the non dominant leg.

5.4.3 Biomechanical Evaluation

The comparison between school and club players for the lower leg and ankle area of the biomechanical evaluation is shown in Table 5.28. In the comparison between school and club players for this area, there were high practically significant differences for the Achilles tendon suppleness test and the supination components of the right rear foot lying and standing tests. There were also differences of medium effect size for the toe positional test ($d=0.66$ Left and $d=0.61$ Right) and the left side supination components in standing and lying ($d=0.72$). The rest of the tests showed differences of small effect size or less between the two groups.

The profile for youth players for the lower leg and foot area show mean values close to normal for the high arch component of the foot arch, the supination component of the rear foot tests, the hypermobility component of the foot mobility tests and the previous injury

questionnaire. The results of the Achilles suppleness test, the low arch component of the foot longitudinal arch test, the pronation component of the rear foot tests and the hypomobility component of mid-foot joint mobility test indicate that between 51.8% and 66.4% of players presented with dysfunctional values in these tests. The toe positional test had a mean value of 1.782 for the left and 1.791 for the right, showing that between 78.2% and 79.1% of players had toes with positional dysfunction or adaptation of the toes.

The average youth player would thus present with adaptation of toes, normal or flat medial foot arches, a normal or pronated rear foot in standing and lying, a normal or hypomobile mid-foot joint with between 42.7% and 51.8% of players also presenting with decreased Achilles tendon suppleness and callusing of the transverse foot arch.

Table 5.28 Comparison of data for school and club soccer players for lower leg biomechanics

	School Players				Club Players				School vs Club Players			
FOOT AND LOWER LEG	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	R Mean	d Values L	d Values R
ACHILLES TENDON SUPPLENESS TEST	1.102	0.31	1.102	0.31	1.803	0.57	1.918	0.59	1.491	1.555	-1.59	-1.81
FOOT LONGITUDINAL TEST												
High Arch	1.020	0.14	1.020	0.14	1.066	0.25	1.066	0.25	1.045	1.045	-0.24	-0.24
Low Arch	1.612	0.49	1.592	0.50	1.607	0.49	1.639	0.48	1.609	1.618	0.01	-0.10
FORE FOOT	1.367	0.49	1.367	0.49	1.410	0.50	1.410	0.50	1.391	1.391	-0.09	-0.09
REAR FOOT STANDING TEST												
Pronation	1.673	0.47	1.673	0.47	1.508	0.50	1.656	0.48	1.582	1.664	0.34	0.04
Supination	1.000	0.00	1.000	0.00	1.115	0.32	1.148	0.36	1.064	1.082	-0.72	-0.82
REAR FOOT LYING TEST												
Pronation	1.694	0.47	1.694	0.47	1.475	0.50	1.623	0.49	1.573	1.655	0.45	0.15
Supination	1.000	0.00	1.000	0.00	1.115	0.32	1.131	0.34	1.064	1.073	-0.72	-0.77
TRANSVERSE ARCH	1.510	0.51	1.510	0.51	1.361	0.48	1.377	0.49	1.427	1.436	0.30	0.27
MID-FOOT MOBILITY TEST												
Hypomobility	1.633	0.49	1.612	0.49	1.426	0.50	1.525	0.54	1.518	1.564	0.42	0.17
Hypermobility	1.020	0.14	1.020	0.14	1.049	0.22	1.033	0.18	1.036	1.027	-0.16	-0.08
TOES	1.918	0.28	1.918	0.28	1.672	0.47	1.689	0.47	1.782	1.791	0.66	0.61
PREVIOUS INJURY	1.082	0.28	1.082	0.28	1.246	0.43	1.197	0.48	1.173	1.145	-0.46	-0.30
DYSFUNCTION SCORE /10	4.592	1.41	4.551	1.42	4.787	1.98	5.393	1.93	4.700	5.018	-0.12	-0.50

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Table 5.29 shows the comparison between the school and club players for the knee area of the biomechanical evaluation. There were high practically significant differences for the quadriceps component of the Thomas test, the patella squint and knee height tests. The left patella tilt test and right leg dysfunction score had differences of medium effect size, with the rest of the tests showing differences of small effect size or less.

The biomechanical profile of all youth players combined for the knee area, indicate that the average player presented with excessive tightness of the quadriceps muscles, normal patella tilt and squint, normal knee height, normal Q-angle, a normal VMO:VL ratio and no previous injuries. The mean dysfunction scores of 1.845 for the left and 2.009 for the right, calculated out of 8, indicate little dysfunction in this area.

Table 5.29 Comparison of data for school and club soccer players for knee biomechanics

KNEE	School Players				Club Players				School vs Club Players			
	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	R Mean	d Values L	d Values R
THOMAS TEST: QUADS	1.408	0.50	1.408	0.50	1.984	0.65	1.967	0.63	1.727	1.718	-1.00	-0.99
KNEE Q-ANGLE	1.061	0.24	1.061	0.24	1.033	0.18	1.033	0.18	1.045	1.045	0.13	0.13
PATELLA SQUINT	1.061	0.24	1.061	0.24	1.541	0.50	1.656	0.48	1.327	1.391	-1.30	-1.65
PATELLA TILT	1.367	0.49	1.367	0.49	1.131	0.34	1.164	0.37	1.236	1.255	0.57	0.47
KNEE HEIGHT	1.571	0.50	1.571	0.50	1.098	0.30	1.098	0.30	1.309	1.309	1.18	1.18
VMO	1.082	0.28	1.061	0.24	1.115	0.32	1.131	0.34	1.100	1.100	-0.11	-0.24
PREVIOUS INJURY	1.081	0.28	1.122	0.33	1.098	0.30	1.230	0.46	1.091	1.182	-0.06	-0.27
DYSFUNCTION SCORE /8	1.633	1.29	1.653	1.30	2.016	1.06	2.295	1.23	1.845	2.009	-0.33	-0.51

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Table 5.30 shows the comparison between school and club players for the hip area of the biomechanical evaluation. There were differences of practical significance for the right leg ITB test, the left leg Hip external rotation test and the right leg dysfunction score. There were also differences of medium effect size for right Hip internal and external rotation, Adductor length and left leg dysfunction score. School players showed better biomechanical results with less dysfunction than the club players. The rest of the tests showed differences of small effect size, with school players having more dysfunction of the Gluteal muscle length test, and club players showing more dysfunction in the other tests.

The biomechanical profile of the average youth soccer player for the hip area, could be described as follows: There is dysfunction with decrease ROM of Hip external rotation, decreased Gluteal muscles length, normal Hip internal rotation and no previous history of injury. Between 38.2% and 62.7% of players will also exhibit decreased muscle length of the Adductor muscles, decreased length of the ITB decreased Iliopsoas muscle length. The mean dysfunction scores for youth players are 3.518 for the left side and 3.864 for the right side.

Table 5.30 Comparison of data for school and club soccer players for hip biomechanics

	School Players				Club Players				School vs Club Players			
HIP	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	R Mean	d Values L	d Values R
ITB	1.367	0.49	1.429	0.50	1.525	0.54	1.967	0.71	1.455	1.727	-0.31	-0.89
ILIOPSOAS	1.327	0.52	1.327	0.52	1.525	0.70	1.574	0.64	1.436	1.464	-0.32	-0.43
GLUTEAL MUSCLES	1.939	0.38	1.939	0.43	1.672	0.77	1.754	0.75	1.791	1.836	0.46	0.31
ADDUCTOR LENGTH	1.245			0.43	1.689			0.79	1.491			-0.73
HIP INTERNAL ROTATION	1.041	0.20	1.041	0.20	1.115	0.32	1.230	0.42	1.082	1.145	-0.28	-0.61
HIP EXTERNAL ROTATION	1.873	0.47	1.873	0.51	2.393	0.64	2.180	0.67	2.145	2.027	-0.94	-0.52
PREVIOUS INJURY	1.082	0.28	1.061	0.24	1.164	0.42	1.230	0.53	1.127	1.155	-0.23	-0.44
DYSFUNCTION SCORE /13	2.837	1.36	2.878	1.41	4.066	2.31	4.656	2.58	3.518	3.864	-0.67	-0.89

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Table 5.31 shows the biomechanical comparison between school and club players for the Lumbo-pelvic area. In the comparison, there was only high practically significant difference for the lumbar coronal view test and the Left rotation test. There were also differences of medium effect size for leg length test, the ASIS, PSIS, Rami, Cleft, Sacral Rhythm test, Thoraco Lumbar fascia test, Lumbar extension and the Right Lumbar rotation tests. There were differences of small effect size for right side flexion tests, lumbar flexion test and the dysfunction scores. The Pelvis bilateral test, Left Side flexion and lumbar sagittal view had differences of less than small effect size, showing that the occurrence of lumbar scoliosis and anterior pelvic tilt is similar in school and club players.

The profile of the average youth soccer player for the Lumbo-pelvic area can be described as follows: There is an excessive anterior tilt of the pelvis as is seen in the Pelvis bilateral position test. There is also normal Lumbar extension, Side flexion, rotation and Lumbar sagittal view. Between 58.18% and 65.45% of players presented with an abnormal Coronal view and decreased Lumbar flexion. Between 41.81% and 44.54% of players also presented with Leg length, ASIS, PSIS, Cleft, Rami and Sacral rhythm asymmetry. The mean dysfunction score for youth players was 5.627 for left side and 5.573 for the right side. This indicates relatively low levels of dysfunction, as the score is calculated out of a maximum of 21 for this area.

Table 5.31 Comparison of data for school and club soccer players for lumbo-pelvic biomechanics

LUMBO PELVIC AREA	School Players				Club Players				School vs Club Players			
	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev	L Mean	R Mean	d Values L	d Values R
LEG LENGTH	1.327			0.52	1.656			0.66	1.509			-0.56
ASIS	1.286			0.46	1.525			0.50	1.418			-0.50
PSIS	1.286			0.46	1.525			0.50	1.418			-0.50
RAMI	1.286			0.46	1.525			0.50	1.418			-0.50
CLEFT	1.286			0.46	1.525			0.50	1.418			-0.50
PELVIS BILATERAL POSITION	1.980			0.14	1.918			0.74	1.945			0.14
THORACO LUMBAR FASCIA	1.469	0.50	1.469	0.50	1.213	0.41	1.180	0.39	1.327	1.309	0.56	0.65
SACRUM RHYTHM	1.286			0.46	1.541			0.50	1.427			-0.53
EXTENSION	1.122			0.33	1.377			0.52	1.264			-0.60
FLEXION	1.531			0.54	1.738			0.63	1.645			-0.35
ROTATION	1.041	0.20	1.041	0.20	1.295	0.46	1.246	0.43	1.182	1.155	-0.77	-0.65
SIDE FLEXION	1.286	0.46	1.286	0.46	1.213	0.41	1.197	0.40	1.245	1.236	0.17	0.21
LUMBAR CORONAL	1.959			0.20	1.410			0.50	1.655			1.57
LUMBAR SAGGITAL	1.224			0.42	1.246			0.43	1.236			-0.05
DYSFUNCTION SCORE /21	5.143	3.06	5.143	3.06	6.016	3.60	5.918	3.54	5.627	5.573	-0.26	-0.23

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

Table 5.32 shows the comparison between school and club players for the neurodynamic area of the biomechanical evaluation. There were differences of high practical significance for Prone knee bend and the right leg Total combined dysfunction score. There was also a medium effect difference for the Neurodynamic dysfunction scores and Left side Total combined dysfunction score. The differences in the combined Total dysfunction score indicate that there were practically significant or at least medium effect size differences between school and club players, with club players having higher dysfunction scores, and therefore, more biomechanical dysfunction than school players. The rest of the tests showed differences of small effect size or less between the two groups.

The neurodynamic profile of the average youth player showed that between 44.54% and 50.91% of players presented with decreased Straight leg raise and Prone knee bend tests. The total dysfunction score for the left side was 17.091 and 17.909 for the right side.

Table 5.32 Comparison of data for school and club soccer players for neurodynamic biomechanics

	School Players				Club Players				School vs Club Players			
NEURODYNAMICS	L Mean	STD Dev	R Mean	STD Dev	L Mean	STD Dev	R Mean	STD Dev	L Mean	R Mean	d Values L	d Values R
STRAIGHT LEG RAISE	1.490	0.51	1.490	0.51	1.508	0.70	1.393	0.64	1.500	1.436	-0.03	0.17
PRONE KNEE BEND	1.204	0.41	1.204	0.41	2.016	0.85	2.197	0.83	1.655	1.755	-1.29	-1.60
SLUMP	1.306	0.47	1.306	0.47	1.180	0.39	1.197	0.44	1.236	1.245	0.29	0.24
DYSFUNCTION SCORE /6	1.020	1.15	1.020	1.15	1.705	1.28	1.787	1.23	1.400	1.445	-0.56	-0.64
TOTAL DYSFUNCTION SCORE /58	15.224	5.01	15.245	5.10	18.590	5.67	20.049	6.23	17.091	17.909	-0.63	-0.85

d=0.2 (small effect) d=0.5 (medium effect) d= 0.8 (large effect)

5.4.4 Summary of Biomechanical Evaluation

In the biomechanical evaluation of the lower leg and foot area, the average youth player presented with adaptation of toes, normal or flat medial foot arches, a normal or pronated rear foot in standing and lying, a normal or hypomobile mid-foot joint with between 42.7% and 51.8% of players also presenting with decreased Achilles tendon suppleness and callusing of the transverse foot arch. This corresponds with the foot profile of a decreased medial arch with associated rear foot pronation and decreased mid-foot mobility.

The biomechanical profile of all youth players combined for the knee area, indicate that the players presented with excessive tightness of the quadriceps muscles, normal patella tilt and squint, normal knee height, normal Q-angle, a normal VMO:VL ratio and no previous injuries. This profile indicates very little dysfunction amongst youth for the knee area, with only quadriceps length as tested with the Modified Thomas Test being decreased.

The profile of youth soccer players for the hip area, could be described as follows: There was shortening of hip external rotators, decreased Gluteal muscles length, normal hip internal rotation and no previous history of injury. Between 38.2% and 62.7% of players also exhibit shortened muscle length of the adductor and Iliopsoas muscles and decreased length of the ITB. The mean dysfunction scores for youth players 3.518 for the left side and 3.864 for the right side. This difference in results for the left and right side could

probably be attributed to more passing and kicking happening with the right leg due to dominance of the right leg in most players.

The profile of youth players for the Lumbo-pelvic area can be described as follows: There was an excessive anterior tilt of the pelvis with normal lumbar extension, side flexion, rotation and lumbar sagittal view without presence of scoliosis. Between 58.18% and 65.45% of players presented with an abnormal coronal view and decreased lumbar flexion. Between 41.81% and 44.54% of players also presented with leg length, ASIS, PSIS, Cleft, Rami and sacral rhythm asymmetry. The similarity of the results for these tests in all players contributed to a new variable called 'SIJ dysfunction' to be formed from the average of the scores for ASIS, PSIS, Cleft, Rami and Sacral rhythm, which will be considered for inclusion in the prediction model.

The neurodynamic results of youth players indicated that between 44.54% and 50.91% of players presented with decreased Straight leg raise and Prone knee bend tests. This indicates restriction of the L4 nerve root as well as the sciatic nerve, which are tested with the two tests. The total dysfunction score for the left and right sides were 17.091 and 17.909 respectively, indicating that there were higher levels of dysfunction on the right side than the left. This increased unilateral dysfunction could probably be attributed to limb dominance and increased use of the one leg for kicking and passing during the game. According to Ekstrand (2003) abnormal biomechanics can lead to increased one sided strain.

5.4.5 Injury Epidemiology

Table 5.33 shows the injury rate comparisons between school and club players. When combined, school and club players (youth players) had 6830 hours of training exposure and 1401 hours of match exposure. The total amount of play exposure during the two seasons for school and club players was 8231 hours. There were a total of 49 training injuries and 52 match injuries. The total combined injury rate for school and club players was 12.27 injuries/1000 hours, with a total match injury rate of 37.12 injuries/1000 match hours. The combined training injury rate was 7.17 injuries/1000 training hours. School players (16.41/1000 hours) had a higher total injury rate than club players (11.51/1000 hours). They also had a higher training injury rate. Ekstrand (2003) reported that a well trained player is less prone to injury and also that increases in skill and technical proficiency decrease injuries. Club players (45.80/1000 hours) had a much higher match injury rate than school players (20.66/1000 hours), which could be attributed to the more intense nature of club matches. The combined match injury rate is lower than that of 47.5/1000 match hours reported by Junge *et al.* (2004). The total injury rate and training injury rate is much lower than the figures reported by Junge *et al.* (2004), but higher than those reported by Le Gall *et al.* (2006), Schmidt-Olsen *et al.* (1991) and Emery and Meeuwisse (2006). These injury rates indicate that school soccer has higher injury levels than club soccer, although this could be attributed to the short span of the school season and the much higher percentage of contact injuries reported in school players (Table 5.36). This higher level of contact injuries could possibly be attributed to better protective equipment used by club players, better pitch conditions and better refereeing in club matches.

Table 5.33 Injury rate comparison: School and Club players

	School	Club	Combined
Training Exposure	796 hours	6034 hours	6830 hours
Match Exposure	484 hours	917 hours	1401 hours
Training Injuries	11	38	49
Match Injuries	10	42	52
Injury Rate	/1000 hours	/1000 hours	/1000 hours
Total	16.41	11.51	12.27
Match	20.66	45.80	37.12
Training	13.82	6.30	7.17

Table 5.34 shows the comparison for different areas of injury between school and club players, as well as the combined total for school and club players. The combined total shows 87.13% of injuries to be of the lower limb area. The individual areas with the highest percentage of injuries were the ankle (25.74%), Knee (19.80%), Thigh (15.84%) and lower leg (14.85%). This is similar to research by Junge *et al.* (2004), which also showed the ankle to be the most injured area with thigh, lower leg and knee being the three next most injured areas. Le Gall *et al.* (2006) also showed the thigh, knee and ankle to be the areas with the most injuries. All previous research show the ankle, knee, lower leg and thigh areas to be the most injured areas, with percentages and ranking varying between studies.

Table 5.34 Injury area comparison: School and Club players

	School	Club	Combined
Area	% of total	% of total	% of total
Lower Limb	76.19	91.1	87.13
Foot	0	1.2	0.99
Ankle	23.81	26.5	25.74
Lower leg	19.05	13.9	14.85
Knee	19.05	20.2	19.80
Thigh	9.52	17.7	15.84
Hip and Groin	4.76	12.6	10.98
Overuse	19.05	8.9	10.98

Table 5.35 compares the severity of injuries between school and club players. The majority of injuries in school players were 'zero day' injuries (57.14%) with 'slight' injuries being the second most common severity of injuries. Club players showed the majority of injuries to be 'slight' (38%) with 'zero day' injuries (30.30%) being the second highest type. Both groups showed 'minor' injuries to be the third highest injury category, with similar percentages (14.29% and 15.2%). Club players showed a higher percentage of 'Mild' and 'Major' injuries. The combined totals show 'zero day' injuries to be the most common type, followed by 'slight' and 'minor'. The injury patterns suggest that, even though school players exhibit higher injury rates, the severity of club injuries are higher, causing more time out of play. 69.7% of club injuries cause time to be lost from play, with only 42.86% of school injuries causing any time to be lost from play. The only injuries of 'major' severity were fractures incurred by club players.

Table 5.35 Injury severity comparison: School and Club players

	School	Club	Combined
Severity	% of total	% of total	% of total
Zero Day (0 days off)	57.14	30.30	35.64
Slight (1-3 days off)	19.05	38.00	33.66
Minor (4-7 days off)	14.29	15.20	14.85
Mild (7-14 days off)	4.76	11.40	9.90
Moderate (14-28 days off)	4.76	3.80	3.96
Major (more than 28 days off)	0.00	1.20	0.99

Table 5.36 shows the injury type comparison for school and club players. In club players, sprain, strains and contusions are the most common types of injuries. The combined totals for school and club players also show sprains, strains and contusions to be the most common type of injuries. Junge *et al.* (2004) reported 31.8% of injuries as strains, 20.3% as sprains and 28.4% as contusions with Deehan *et al.* (2007) reporting 37% of injuries as

strains, 18% as sprains and only 5.8% as muscular contusions. All previous injury studies show large percentages of strain and sprain injuries. The high percentage of contusion injuries in school players could be directly linked to the large percentage of contact injuries recorded in school players. Price *et al.* (2004) had a similar high figure of contact injuries (66% of total) with contusions being the most common type of injuries (60%). The lower levels of non-contact injuries amongst school players has a strong correlation with the lower levels of biomechanical dysfunction noted for school players during the biomechanical evaluation.

Table 5.36 Injury mechanism comparison: School and Club players

	School	Club	Combined
Type	% of total	% of total	% of total
Contusion	47.62	22.8	27.72
Sprain	19.05	34.2	30.69
Strain	14.29	31.6	27.72
Overuse	19.05	8.9	10.89
Fracture	0	3.8	2.97
Non Contact	38.10	57	52.47
Contact	61.90	43	46.53

5.4.6 Summary of Injury Epidemiology

In the epidemiological study on youth players, there were a total of 49 training injuries and 52 match injuries. The total injury rate for youth players was 12.27 injuries/1000 hours, with a total match injury rate of 37.12 injuries/1000 match hours. The combined training injury rate was 7.17 injuries/1000 training hours. 87.13% of injuries were of the lower limb area and the individual areas with the highest percentage of injuries were the ankle (25.74%), knee (19.80%), thigh (15.84%) and lower leg (14.85%). The totals for youth players indicate sprains (30.69% of total), strains (27.72% of total) and contusions (27.72% of total) to be the most common mechanism of injuries. The severity of injuries

show 'zero day' injuries to be the most common type (35.64%), followed by 'slight' (33.66%) and 'minor' (14.85%). School players had higher injury rates than club players, but the severity of injuries to club players was higher, with more absence from play. Non contact injuries accounted for 52.47% of the total with 46.53% being contact injuries. School players had lower levels of non-contact injuries than club players, which correlated well with lower dysfunction scores noted for school players during the biomechanical evaluations. This shows that there is a definite relationship between levels of biomechanical dysfunction and the percentage of non-contact injuries in youth players, which forms the premise of the creation of a prediction model for non-contact youth soccer injuries.

5.5 SUMMARY

This chapter contained the results of the empirical investigation of the research study. The proprioceptive, plyometric and biomechanical profiles of school, club and youth players were discussed and the results of the different groups were compared to each other. A profile for club, school and youth players was also created, indicating dysfunction and characteristics typical to different player groups. The results of Costa Paptic Soccer Academy players evaluated by Serfontein and Spamer (2008) show larger similarity to Platinum Stars club players than to school players, indicating that levels of exposure could have an influence on biomechanics. Unfortunately, injury data was not available for the Costa Paptic Soccer Academy players. The injury epidemiology for all the groups was also discussed and compared. The direct correlation between increased biomechanical dysfunction and increases in non-contact injuries was also noted. This

biomechanical profile will be used with the collected injury data to create a prediction model for non-contact youth soccer injuries.

The next chapter will discuss the logistical regression process and the creation of a prediction model for non-contact injuries amongst youth soccer players, and injuries to specific anatomical areas. The testing of the model will also be discussed.

CHAPTER 6

CREATION OF THE PREDICTION MODEL

- 6.1 INTRODUCTION**
- 6.2 CREATION AND EVALUATION OF THE PREDICTION MODEL
FOR ALL INJURIES**
- 6.3 CREATION AND EVALUATION OF THE PREDICTION MODEL
FOR GROIN INJURIES**
- 6.4 SUMMARY**

CHAPTER 6

CREATION OF THE PREDICTION MODEL

6.1 INTRODUCTION

This chapter contains the steps taken to create a prediction model for soccer injuries in youth players. It also shows different tests used to validate the model and test its accuracy. It also contains the steps used to create a prediction model for groin injuries. These models can be used in future to predict the probability of injuries in youth soccer players.

6.2 CREATION AND EVALUATION OF THE PREDICTION MODEL FOR ALL INJURIES

The proprioceptive and plyometric testing, biomechanical evaluation, dominance and dysfunction scores for each area contained too many variables to use with logistic regression analysis, as it would negatively affect the validity of the model created. A cluster analysis on variables was used to decrease the number of variables that were considered for inclusion in the prediction model. Using a cluster analysis of the Statistica software (STATSOFT, Inc., 2004) for variables in each individual biomechanical area, the number of variables considered for inclusion in the prediction model was decreased. Figures 6.1, 6.2, 6.3, 6.4 and 6.5 show the cluster analysis for each area. Figure 6.6 shows a cluster analysis using Ward's method and the similarity matrix of intercorrelations subtracted from 1, for all test results combined. At the end of this process, 26 variables (including left and right sides for many of them) were considered for inclusion in the overall injury prediction model.

Key to Figures:

TOE_L:	Toe positional test left leg
TOE_R:	Toe positional test right leg
RFL_PR_L:	Rear foot lying pronation component left leg
RFL_PR_R:	Rear foot lying pronation component right leg
RFL_SUP_L:	Rear foot lying supination component left leg
RFL_SUP_R:	Rear foot lying supination component right leg
RFS_PR_L:	Rear foot standing pronation component left leg
RFS_PR_R:	Rear foot standing pronation component right leg
RFS_SUP_L:	Rear foot standing supination component left leg
RFS_SUP_R:	Rear foot standing supination component right leg
SLUMP_L:	Slump neurodynamic test left side
SLUMP_R:	Slump neurodynamic test right side
KN_H_L:	Knee height test left side
KN_H_R:	Knee height test right side
TILT_L:	Patella tilt left side
TILT_R:	Patella tilt right side
SF_L:	Lumbar side flexion left side
SF_R:	Lumbar side-flexion right side
SLR_L:	Straight leg raise test left side
SLR_R:	Straight leg raise test right side
LX_FLEX:	Lumbar flexion test
TLF_L:	Thoraco-lumbar fascia length test left side
TLF_R:	Thoraco-lumbar fascia length test right side
LX_COR:	Lumbar coronal view
BAL_L:	Balance test left leg
BAL_R:	Balance test right leg
SACR_RHYTHM:	Sacral rhythm test
CLEFT:	Sacral cleft test
RAMI:	Pelvic rami positional test
ASIS:	Anterior Superior Iliac Spina Positional test
PSIS:	Posterior Superior Iliac Spina Positional test
LEG_LENGTH:	Leg length test
PSOAS_L:	Hip flexor length test (Thomas test) left side
PSOAS_R:	Hip flexor length test (Thomas test) right side
ROT_L:	Lumbar rotation test left side
ROT_R:	Lumbar rotation test right side
ITB_L:	Iliotibial band length test (Thomas test) left side
ITB_R:	Iliotibial band length test (Thomas test) right side
QUADS_L:	Quadriceps length test (Thomas test) left side
QUADS_R:	Quadriceps length test (Thomas test) right side
L4_L:	Prone knee bend neurodynamic test left side
L4_R:	Prone knee bend neurodynamic test right side
LX_EXT:	Lumbar extension test
TA_L:	Achilles tendon suppleness test left leg
TA_R:	Achilles tendon suppleness test right leg
D_BIL:	Plyometric ratio, Dominant leg: Bilateral leg
ND_BIL:	Plyometric ratio, Non-Dominant leg: Bilateral leg

D_ND_BIL:	Plyometric ratio, Non-Dominant plus Dominant leg: Bilateral
leg	
PLYO_ND:	Plyometric jump height non-dominant leg
PLYO_D:	Plyometric jump height dominant leg
PLYO_BIL:	Plyometric jump height bilateral legs
Q_ANGL_L:	Knee Q-angle left side
Q_ANGL_R:	Knee Q-angle right side
MM_HYPO_L:	Midfoot mobility test hypomobility component left side
MM_HYPO_R:	Midfoot mobility test hypomobility component right side
MM_HYPER_L:	Midfoot mobility test hypermobility component left side
MM_HYPER_R:	Midfoot mobility test hypermobility component right side
FL_HA_L:	Foot longitudinal arch high arch component left side
FL_HA_R:	Foot longitudinal arch high arch component right side
FL_LA_L:	Foot longitudinal arch low arch component left side
FL_LA_R:	Foot longitudinal arch low arch component right side
PREV_KN_INJ_L:	Previous knee injury left side
PREV_KN_INJ_R:	Previous knee injury right side
LX_SAGG:	Lumbar sagittal view
PELVIS_BIL:	Pelvis bilateral position test
PREV_HIP_INJ_L:	Previous hip and groin injury left side
PREV_HIP_INJ_R:	Previous hip and groin injury right side
PREV_ANKL_INJ_L:	Previous ankle injury left side
PREV_ANKL_INJ_R:	Previous ankle injury right side
VMO_L:	Vastis Medialis Oblique: Vastis Lateralis ratio left knee
VMO_R:	Vastis Medialis Oblique: Vastis Lateralis ratio right knee
SQUINT_L:	Patella squint test left knee
SQUINT_R:	Patella squint test right knee
HIR_L:	Hip internal rotation ROM test left side
HIR_R:	Hip internal rotation ROM test right side
HER_L:	Hip external rotation ROM test left side
HER_R:	Hip external rotation ROM test right side
ADD:	Hip adductor length test
GLUT_L:	Gluteal muscle length test left side
GLUT_R:	Gluteal muscle length test right side
TR_ARCH_L:	Transverse foot arch test left side
TR_ARCH_R:	Transverse foot arch test right side
FFOOT_L:	Forefoot positional test left side
FFOOT_R:	Forefoot positional test right side
DOM:	Limb Dominance

Figure 6.1 Cluster analysis of Lower leg and ankle area

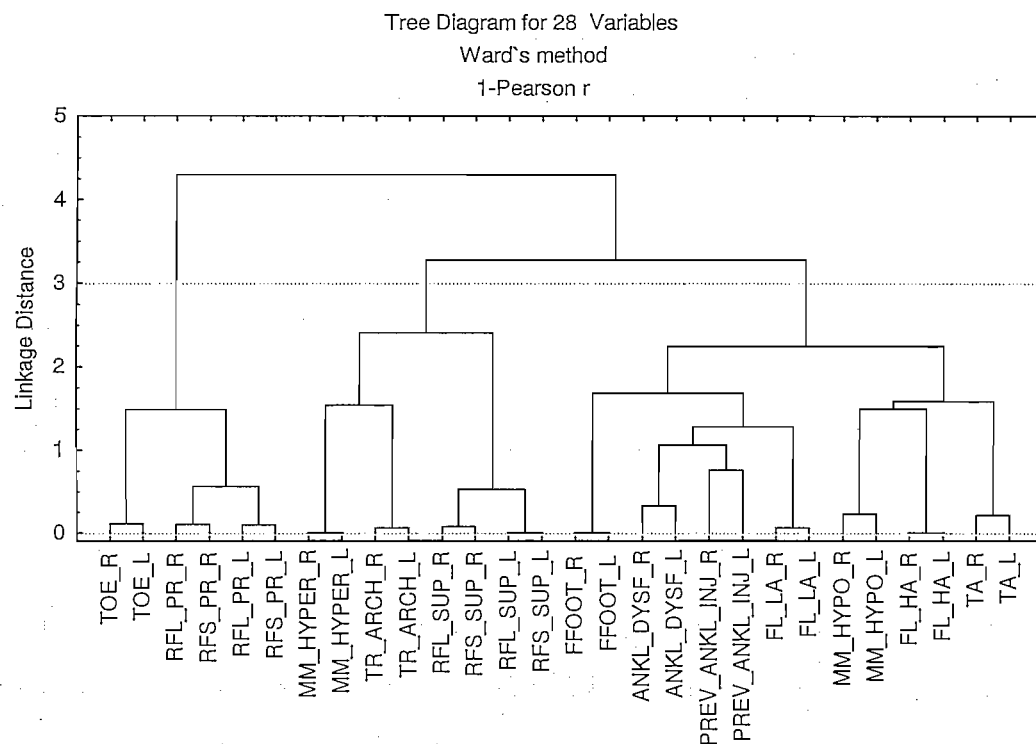


Figure 6.2 Cluster analysis of Knee area

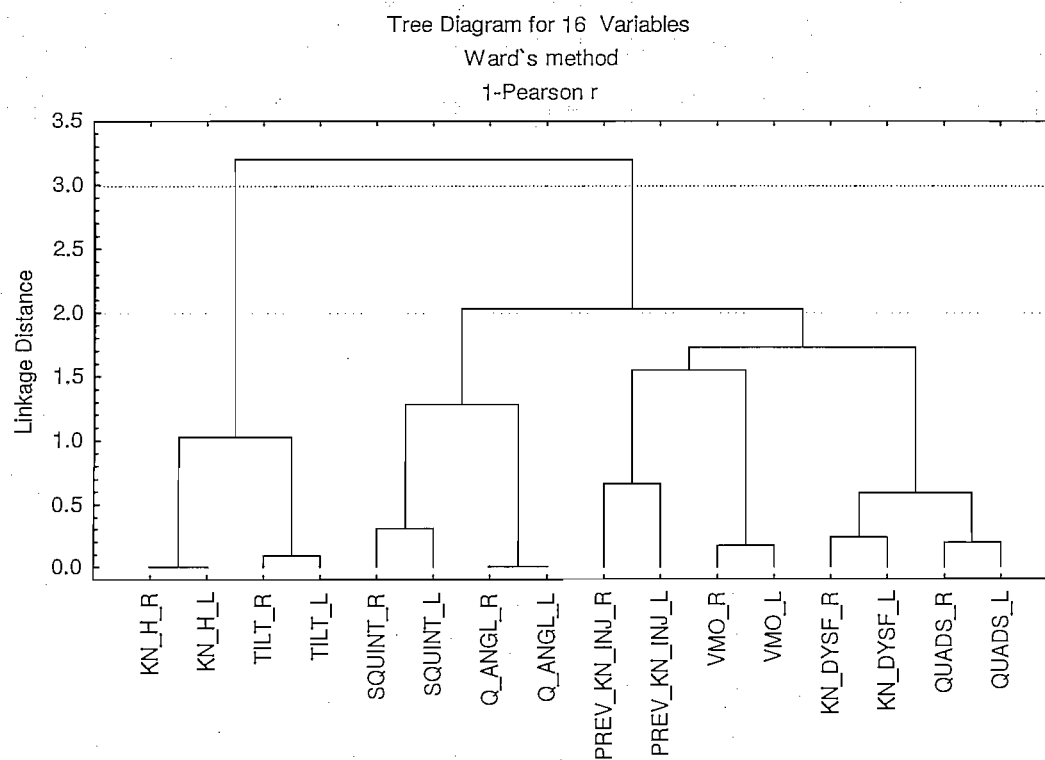


Figure 6.3 Cluster analysis of Hip and groin area

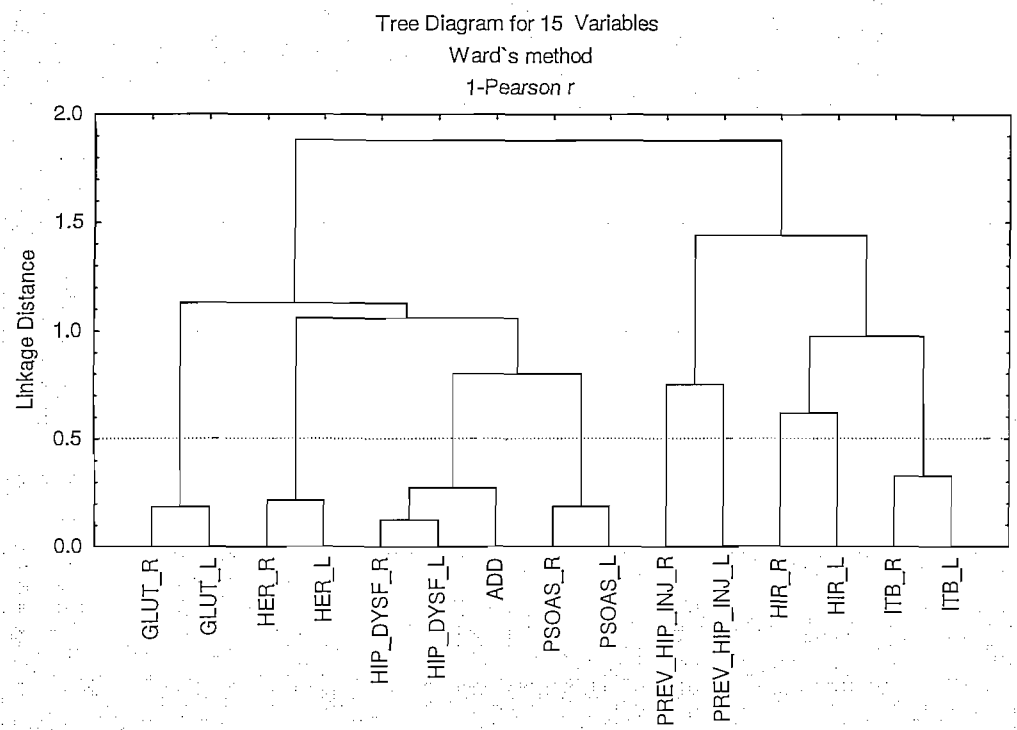
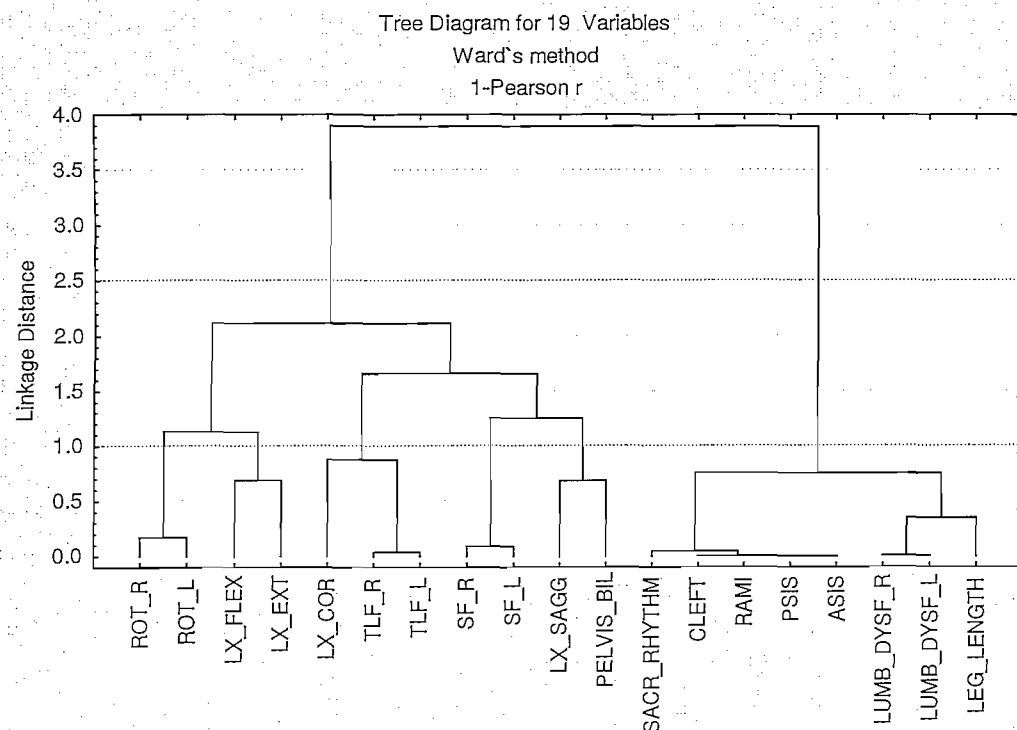


Figure 6.4 Cluster analysis of Lumbo-pelvic area



The next step in the creation of a prediction model was to identify the variables that discriminate best between injured and non-injured players. This was done using stepwise logistic regression analysis. For the analysis, the variables with a left and a right side were combined to a single value, equal to the worst result from the two sides. After the analysis, ten variables were selected, according to the criteria for the procedure, for inclusion in the prediction model to predict non contact injuries in youth soccer players. The odds for a variable like TOE will be the number of players with TOE = 1, relative to the number with TOE = 2, while the odds ratio is the ratio of the odds for all the players in the injury group vs. the non-injury group. Table 6.1 shows the ten variables with their odds ratios and p-values. P-values smaller than 0.05 are considered important, but the SAS statistical software (SAS Institute, Inc., 2003) included four variables with p-values larger than 0.05, which contributed to the efficacy of the prediction model. Odds ratios with a value of 1.5 are considered to have a small effect, odds ratios of 2.5 are considered to have medium effect and odds ratios of 4.5 are considered to have a large effect (Breytenbach, 2008).

Table 6.1 Results of stepwise logistic regression analysis for all injuries

Variable	Odds Ratio	p-values
Toe (toe)	3.663	0.1729
Previous ankle injury (prev_ankl_inj)	6.308	0.0372
Ankle dysfunction (ankl_dysf)	1.282	0.1735
SIJ dysfunction (SIJ_dysf)	72.603	0.0217
Lumbar extension (LX_EXT)	3.993	0.0849
Straight leg raise (SLR)	3.671	0.0159
Psoas length (PSOAS)	3.175	0.1401
Knee squint (Squint)	6.217	<0.0001
Gluteus length (gluts)	2.577	0.0357
Lumbar dysfunction (Lumb_dysf)	1.680	0.0040

The prediction model created from the stepwise analysis presents the probability of any injury as follows:

$$P(\text{injury}) = \frac{\exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}{1 + \exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}$$

a = Toe dysfunction

b = Previous ankle injury

c = Ankle dysfunction

d = SIJ dysfunction

e = Lumbar Extension

f = Straight Leg Raise

g = Psoas length

h = Patella squint

i = Gluteal muscle length

j = Lumbar dysfunction

P = probability of non contact injury

$\exp(x) = e^x$, with e the constant 2.7183

In the ankle area, the toe positional test, previous ankle injury history and combined ankle dysfunction score were included in the prediction model. In the knee area, the patella squint test was included in the model. In the hip area, the Psoas component of the Thomas test was included, along with the Gluteal muscle length test. In the lumbo-pelvis area, the SIJ dysfunction (average of Leg length, ASIS, PSIS, Rami, Cleft and Sacral rhythm tests), lumbar extension test and lumbar dysfunction scores were included in the prediction model. In the neurodynamic area, the Straight leg raise test was included in the prediction model. The prediction model thus contains tests from all five of the biomechanical areas of the evaluation. Peng, Lee and Ingersoll (2002) recommend a minimum observer-to-predictor ratio of 10 to 1, with a minimum sample size of 100. This research had 110 participants, of which three were eliminated from the statistical process because of missing data. The 107 participants used for prediction and the prediction model containing ten variables, gives an observer-to-predictor ratio of 10.7, which indicates an adequate sample size.

Using the Hosmer and Lemeshow inferential goodness-to-fit test on the model (Hosmer and Lemeshow, 2000), it yielded a $X^2(8)$ of 0.7204 which was not significant ($p > 0.05$), suggesting that the model fit the data well. A cross-validation method was used to re-

allocate players in the injury and non-injury groups by means of the model. This was done by excluding the first player from the data set and predicting his probability for an injury by using the prediction model based on the remainder of the players and then classifying him into one of the two groups. This process is repeated for all players by using the SAS software (SAS Institute, Inc., 2003). Table 6.2 shows the observed and predicted frequencies for injury amongst youth soccer players. Using this classification table documenting the validity of the predicted probabilities, the sensitivity and specificity of the prediction model can be evaluated.

Table 6.2 Predicted and observed frequencies of injuries

	Predicted		
Observed	Not Injured	Injured	% Correct
Not Injured	74	4	94.87
Injured	10	19	65.52
Overall % Correct			86.91

Sensitivity measures the proportion of correctly classified injuries, whereas specificity measures the proportion of correctly classified uninjured players. The false positive rate measures the proportion of observations misclassified as injuries over all the predicted injuries. The false negative measures the proportion of observations misclassified as uninjured over all those classified as non-injuries (Peng, Lee and Ingersoll, 2002). The sensitivity of the model is calculated by $19 / (19 + 10) = 65.52\%$ with the specificity calculated as $74 / (74 + 4) = 94.87\%$. False positive predictions are calculated by using $4 / 23 = 17.39\%$ and false negatives are calculated by using $10 / 84 = 11.90\%$. Overall, the model correctly predicted 86.91% of players as either injured or not-injured.

Using the effect size index for improvement over chance (I) (Huberty, 1994), the prediction model showed an I value of 0.66888. Guidelines for effect size of I shows that $I < 0.15$ to have small effect size, with $0.2 < I < 0.3$ having medium effect size and $I > 0.35$ having a

large effect size (Breytenbach, 2008). The observed I value of 0.67 thus indicates a large effect size.

The I-value of the prediction model ($I = 0.67$), along with the sensitivity (65.52%), specificity (94.87%), overall correct percentage of prediction (86.91%) and Hosmer and Lemeshow interferential goodness-to-fit value ($X^2(8)$ of 0.7204), all show this prediction model to be a valid and accurate prediction tool for non contact youth soccer injuries.

The implementation of the model is achieved by substituting the individual test data of a player for the tests included in the prediction model following the completion of the biomechanical evaluation. A P (probability of injury)-value will then be given. This P-value indicates the risk of non-contact injury that the individual player has. A P-value of 1 indicates a 100% risk of injury and a P-value of 0.01 a 1% chance of injury.

6.3 CREATION AND EVALUATION OF THE PREDICTION MODEL FOR GROIN INJURIES

A second prediction model, for the prediction of hip and groin injuries, was also created using logistical regression statistics. The number of variable considered for inclusion in the prediction model was decreased using a cluster analysis (Figure 6.3). Variables form other biomechanical areas that might affect the injuries were also included. After the cluster analysis, 12 variables were considered for inclusion in the hip and groin injury prediction model. Using stepwise logistic regression analysis, seven variables were included in the prediction model. Table 6.3 shows the seven variables with their adjusted odds ratios as well as p values. P-values smaller than 0.05 are considered important, but the SAS statistical software (SAS Institute, Inc., 2003) included five variables with p-values larger

than 0.05. Odds ratios with a value of 1.5 are considered to have a small effect, odds ratios of 2.5 are considered to have medium effect and odds ratios of 4.5 are considered to have a large effect (Breytenbach, 2008). All the odds ratios for this logistic analysis showed odds ratios of large effect. Prediction models for injuries to other specific anatomical areas were also evaluated, but did not fit prediction models.

Table 6.3 Results of stepwise logistic regression analysis for groin injuries

Variable	Odds Ratio	p-values
SIJ dysfunction (SIJ_dysf)	>999.999	0.0028
Previous knee injury (prev_knee_inj)	>999.999	0.2716
Previous hip injury (prev_hip_inj)	66.497	0.2063
Limb dominance (Dom)	>999.999	0.0166
Lumbar extension (LX_EXT)	6.910	0.3390
Straight leg raise (SLR)	>999.999	0.0640
Non Dominant/Bilateral plyometric (ND_Bil)	>999.999	0.1288

The prediction model created from the stepwise analysis for the probability of groin injuries presents as follows:

$$P(\text{Groin injury}) = \frac{\exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}{1 + \exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}$$

d = SIJ dysfunction

k = Previous knee injury

m = Previous hip injury

e = Lumbar extension

f = Straight leg raise

n = Limb dominance

p = ND/Bil plyometric ratio

P = probability of groin injury

$\exp(x) = e^x$, with e the constant 2.7183

The prediction model for hip and groin injuries include the variables of SIJ dysfunction, previous knee injury, previous hip injury, lumbar extension, straight leg raise, dominance and the ratio of non-dominant leg to bilateral legs plyometric height. There were 107 observations taken into account for the creation of the model, which ultimately contained seven predictors. A suggested minimum observer-to-predictor ratio of 10:1 is recommended

by Peng, Lee and Ingersoll (2002). When this recommendation is considered for the groin injury prediction model, it can be seen that it has a sufficient observer-to-predictor ratio (15.29:1), combined with a sample size larger than 100.

When examining this model for efficacy, the Hosmer and Lemeshow inferential goodness-to-fit test (Hosmer and Lemeshow, 2000) of the model yielded a $X^2(8)$ of 0.77, which is considered significant ($p > 0.05$). This reflects that the data fits the model well. A cross validation method was used to classify players back into injured and non-injured groups using the SAS software (SAS Institute, Inc., 2003). Table 6.4 shows the predicted and observed frequencies of hip and groin injuries amongst youth soccer players. A classification table that reflects the validity of the predicted probabilities can be used to evaluate the specificity and sensitivity for the model.

Table 6.4 Predicted and observed frequencies of hip and groin injuries

Observed	Predicted		% Correct
	Not Injured	Injured	
Not Injured	99	2	98.02
Injured	2	4	66.67
Overall % Correct			96.26

Specificity measures the proportion of correctly classified uninjured players with sensitivity measures the correctly classified injured players. Once again, the proportion of observations misclassified as injuries gives the false positive rate, where the proportion of observations misclassified as uninjured gives the false negative rate (Peng, Lee and Ingersoll, 2002). The sensitivity of the hip and groin injury prediction model is calculated by $4 / (4 + 2) = 66.67\%$. The specificity is calculated using $99 / (99 + 2) = 98.01\%$. False positive predictions are calculated using the following equation: $2 / 6 = 33.33\%$. The false negatives are equated using $2 / 101 = 1.98\%$. When the total of all correctly predicted players is

examined, it shows that 96.26% of all players were classified correctly as either having a hip and groin injury or not.

When the model is evaluated using the effect size index for improvement over chance (I) (Huberty, 1994), an I value of 0.65 is given by the model. I values larger than 0.35 are considered to have a large effect (Breytenbach, 2008)

When all the validifying tests are examined, the I-value (0.65), sensitivity (66.67%), specificity (98.01%), false negatives (1.98%), false positives (33.33%) and Hosmer and Lemeshow goodness-to-fit value ($X^2(8) = 0.77$) and the overall percentage of correct prediction (96.26%) all show that this model is an accurate prediction tool for hip and groin injuries amongst youth soccer players.

Using the hip and groin prediction model, combined with the injury prediction model, injuries in youth soccer players can be predicted. The data for each player should first be substituted into the injury prediction model; to determine the chance of injury during the season. The data should then be substituted into the hip and groin injury prediction model, determining the chance of hip and groin injuries during the season. The results from the groin injury prediction model could then be used to exclude groin injuries amongst players. A negative result for the hip and groin injury, which showed a false negative percentage of 1.98%, could be used to determine that an injury that was predicted using the overall injury prediction model, would not be a hip and groin injury. The prehabilitation programme could then be adapted to focus on areas other than the hip and groin area.

6.4 SUMMARY

This chapter contained the process that was used to create an overall injury prediction model for youth players as well as a prediction model for hip and groin injuries. The models were also tested for validity using various statistical methods. Both the overall injury model and the hip and groin injury model showed to be valid to predict injury amongst youth soccer players. The next chapter will contain a summary of the literature review, the empirical results and the creation of the prediction model. It will also contain the conclusions of the research objectives as stated in chapter 1.

CHAPTER 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

- 7.1 INTRODUCTION**
- 7.2 SUMMARY OF LITERATURE REVIEW**
- 7.3 CONCLUSIONS OF EMPIRICAL RESEARCH**
 - 7.3.1 Physical Profiling**
 - 7.3.1.1 Physical Profile of School Players**
 - 7.3.1.2 Physical Profile of Club Players**
 - 7.3.1.3 Physical Profile of Youth Players**
 - 7.3.2 Injury Epidemiology**
 - 7.3.2.1 Epidemiology of School Players**
 - 7.3.2.2 Epidemiology of Club Players**
 - 7.3.2.3 Epidemiology of Youth Players**
 - 7.3.3 Creation of Prediction Model**
 - 7.3.4 Preventative Training Programme**
- 7.4 RECOMMENDATIONS**
 - 7.4.1 Shortcomings of the study**
 - 7.4.2 Recommendations for Future Research**

CHAPTER 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

The aim of this research study was firstly to create a biomechanical profile of a group of South African youth club and school soccer players. An epidemiological profile was also created over the two season period of the research. The third aim was to create a prediction model for the prevention of non contact soccer injuries amongst youth players, based on the physical and epidemiological profiles. Furthermore, a preventative training programme is included in Annexure E, which could be used for pre-season training of youth players with the aim of reducing non-contact injuries during the season that followed. This chapter contains a summary of the literature review, the empirical research as well as conclusions drawn from these. It also contains recommendations on implementation of the research, future research recommendations and identifies shortcomings of the study.

7.2 SUMMARY OF LITERATURE REVIEW

Soccer is a game played by two teams in a rectangular field. Players attempt to knock a ball through the opponents' goal post using any part of the body except the arms below the elbow and the hands. One player on each team guards the goal and is called the goalkeeper. Soccer is a free-flowing game that requires little equipment and has relatively few rules. All that is needed to play is an area of open space and a ball. This is probably one of the reasons for the sport's immense popularity. Much of the world's soccer is played informally, without field markings or real goals. Soccer is the world's

most popular sport, played by people of all ages in about 200 countries. The sport has millions of fans throughout the world (Encarta, 2007).

In the United States, Canada and South Africa the game is referred to as 'soccer'. The word 'soccer' is a slang corruption of the abbreviation 'assoc', which is derived from the official name 'association football'. Outside these countries the sport is commonly called 'football', or 'fútbol' in Spanish-speaking countries, where the game is very popular. The Federation Internationale de Football Association (FIFA) is the worldwide governing body of soccer (Encarta, 2007).

According to Gerhardt (2004) the contemporary history of soccer spans more than a hundred years and began in England in 1863 when rugby football and soccer branched off from each other and the world's first football (soccer) association was founded. This first association was the Football association in England. Both forms of the game though, seem to stem from a common root. Their early history reveals at least six different games back to which the origins of the game could be traced. Playing games with the feet has been going on for thousands of years.

In South Africa, there were 1.8 million registered football players in 2002/2003 (Alegi, 2004). Football has huge financial revenues, with corporate sponsorships in South Africa in 2003 reaching R 640 million (Alegi, 2004). In England, the Premier football league created revenue to the amount of £1.33 billion in the 2003-2004 season (Tunaru *et al.*, 2005). Injuries to players could have serious financial implications for clubs and for the players themselves. Tunaru *et al.* (2005) also reflected that a strong correlation exists between a club's expenditure on player

salaries and its league performance, suggesting that players are high value assets. Youth players are predominantly amateurs and have no financial value for their clubs or schools, but their continued health and safety are still of vital importance. There are some clubs which contract players at 19 years of age in preparation for playing in their senior sides and these young players should be well looked after to ensure a long career playing soccer.

From the research done on professional male soccer, it can be seen that all the studies are in agreement that the lower limb is the body part that is most often injured during play; accounting for between 77% and 92% of all injuries (Hawkins & Fuller, 1999; Morgan & Oberlander, 2001; Hawkins *et al.*, 2001; Häggelund *et al.*, 2003; Chougale *et al.*, 2005; Waldén *et al.*, 2005a; Waldén *et al.*, 2005b; Waldén *et al.*, 2005c). Injury rates in professional soccer ranges between 6.2 and 14.4 injuries/1000 playing hours. Match injury rates (between 20.6 and 35.3 injuries/1000 hours) are much higher than the rate of those occurring during training (between 2.9 and 11.8/1000 hours) (Hawkins & Fuller, 1999; Morgan & Oberlander, 2001; Häggelund *et al.*, 2003; Waldén *et al.*, 2005a; Waldén *et al.*, 2005b; Waldén *et al.*, 2005c). The number of non contact injuries recorded in these epidemiological studies ranged between 8% and 58% of the total injuries.

These findings can lead us to the following conclusions: as the majority of soccer injuries occur in the lower limb, any injury prevention should be aimed at this body area. Injury rates are much higher in matches than in training and could be due to the higher intensity of match play. The intensity of training should be increased, to better prepare players for match conditions and thus possibly lower the injury rate in

matches. The causes of non contact injuries need to be found, as this high number of non-contact injuries (ranging between 8% and 52%) (Hawkins & Fuller, 1999; Morgan & Oberlander, 2001; Hawkins *et al.*, 2001; Häggelund *et al.*, 2003; Chougale *et al.*, 2005; Waldén *et al.*, 2005a; Waldén *et al.*, 2005b; Waldén *et al.*, 2005c) could possibly be reduced by preventative training programmes. This study aims to examine these causes and develop a preventative training programme to address them.

Injury rates in women's soccer ranged from 1.93 injuries/1000 players hours to 12.2 injuries/1000 player hours, which is lower than the rate recorded for male players. This is contrary to the statement by Lilley *et al.* (2002). This could possibly be attributed to the outdated nature of the comparative literature used by Lilley *et al.* (2002). Lower limb injuries ranged between 60% and 88% of all injuries. This is similar to the high percentages noted in male players. Match injuries incidences for all the studies on female players were similar, ranging between 12.63 injuries/1000 match hours and 24 injuries/1000 match hours. Overuse injuries ranged between 16% and 31.1% of total injuries, which is also similar to studies on male players. It can be seen that there are similar injury trends that were recorded amongst male and female players and that injury prevention models would thus need to address similar types of injuries and injury related problems. Engstrom *et al.* (1991) makes the important observation that the majority of overuse injuries could probably be prevented by changing the character of training.

Various studies on youth soccer players indicate that between 70.7% and 90% of all recorded injuries were of the lower limb, similar to adult male and female soccer. The injury rate per player per season range between 0.4 and 1.8 for these studies on youth

players with an injury occurrence rate between 3.7 injuries /1000 hours and 27.9 injuries /1000 hours (Schmidt-Olsen *et al.*, 1991; Junge *et al.*, 2004; Price *et al.*, 2004; Emery & Meeuwisse, 2006; Le Gall *et al.*, 2006; Deehan *et al.*, 2007). Strains and sprains are generally the types of injury with the highest occurrence in youth soccer players. Between 14.9% and 69% of injuries were recorded as non-contact or overuse injuries. Price *et al.* (2004) recommend that strategies be implemented to try to reduce the number of strains, sprains and non-contact injuries that are prevalent in youth football. Deehan *et al.* (2007) further stress that the prevention of injury is crucial to minimising longer-term degenerative joint disease and persistent dysfunction in youth soccer players.

In all the epidemiological research reported in this research study, certain patterns are clearly visible through all codes of play, age groups and sexes. The lower limb is the area which sustains the most injuries at all levels of play. Youth players show figures of 70% to 90% (Schmidt-Olsen *et al.*, 1991; Junge *et al.*, 2004; Price *et al.*, 2004; Emery & Meeuwisse, 2006; Le Gall *et al.*, 2006; Deehan *et al.*, 2007), females 60% to 82% (Engstrom *et al.*, 1991; Östenberg & Roos, 2000; Lilley *et al.*, 2002; Giza *et al.*, 2005; Faude *et al.*, 2005; Jacobson & Tegner, 2006) and males 85% to 92% (Hawkins & Fuller, 1999; Morgan & Oberlander, 2001; Hawkins *et al.*, 2001; Häggelund *et al.*, 2003; Chougle *et al.*, 2005; Waldén *et al.*, 2005a; Waldén *et al.*, 2005b; Waldén *et al.*, 2005c). Injury prevention should thus be focused on this area of the body. Overuse and non contact injuries also amount to a large percentage of all injuries. These injuries could possibly be avoided by taking preventative measures and Engstrom *et al.* (1991) observes that the majority of overuse injuries could probably be prevented by changing the character of training. Price *et al.* (2004)

recommend further research to evaluate the exposure to injuries at youth level, which this study will also do. Le Gall *et al.* (2006) state that players from all age groups are more at risk of sustaining injuries, and especially overuse disorders, during the first few competitive months of the season. This literature review shows that soccer injuries at all levels of play and competition show similar trends, such as players who are more prone to injury at the beginning of the season, especially with overuse injuries, body areas injured and type of injuries. This theoretically makes creating universal preventative programmes and prediction models a possibility with strong evidence that pre-season screening could be used to try and determine deficiencies which may lead to injuries.

All the epidemiological research shows that non contact and overuse injuries were found to represent a sizable percentage of all injuries occurring in youth players (Schmidt-Olsen *et al.*, 1991; Junge *et al.*, 2004; Price *et al.*, 2004; Emery & Meeuwisse, 2006; Le Gall *et al.*, 2006; Deehan *et al.*, 2007). Existing research on current prediction models and preventative measures was also examined, which was then used for the compilation of an appropriate test battery for evaluation of youth soccer players and also substantiated the inclusion of the selected test parameters in the test battery used for this study. Further literature on biomechanics (Erasmus, 2006; Myer *et al.*, 2005; Rolls & George, 2004; Witvrouw, Mahieu, Danneels & McNair, 2004; Dabedo, White & George, 2004; Maganaris, Natrici, Almekinders & Maffulli, 2004; Witvrouw, Danneels, Asselman, D'Have & Cambier, 2003; Ribeiro *et al.*, 2003; Hattingh, 2003; Suter, McMorland, Hertzog & Bray, 1999; Heidt *et al.*, 2000; Neely, 1998; Christensen, 1997; DonTigny, 1990), plyometrics (Serfontein, 2006; Moss, 2002; Voight & Tippet, 1999; Swanik & Swanik, 1999), proprioception and

balance (Verhagen, Van der Beek, Twisk, Bouter, Bahr, & Van Mechelen, 2004; Stasinopoulos, 2004; Baltaci & Kohl, 2003, Murphy *et al.*, 2003) was also examined, giving an in-depth background on the influence of these parameters on injuries and so doing, validate the research design and the inclusion of the selected testing parameters.

It could be seen from all the preceding research that there is a basis for injury prediction in sports participants, and especially soccer players, based on pre-season evaluation of a number of factors. Previous injury was identified along with leg dominance, postural problems and musculoskeletal deficiencies. It could also be seen from the discussed literature that there were a number of predictive studies done on sports injuries. None of these previous studies used the test battery combined in this research, but some contained elements from it.

A biomechanical evaluation compiled by Hattingh (2003) contained elements of evaluation of most of the suggested causes for overuse injuries amongst sportsmen. It was also easy to administer by a trained professional and required minimal equipment. This made it ideal for the South African youth soccer milieu with its limited resources and finances. Based on all of these reasons, it was selected as the biomechanical evaluation model to be used in this research study. It had also been proven effective in evaluating and helping with prevention of injuries in subsequent studies by Erasmus (2006) and Steenkamp (2006) on youth rugby players. This model evaluates mobility, dynamic stability and neural mobility. Testing would focus on the lower limb, pelvic and lower back area, as research on epidemiology described

previously shows that the majority of soccer injuries among youth players occur in these areas.

There is an abundance of literature supporting the theory that a decrease in proprioception and balance could indicate and increased risk of injuries in the ankle and knee. Research also showed that proprioceptive and balance training could help decrease injury occurrence, which was also linked to increased balance and proprioception in measurements (Verhagen *et al.*, 2005; Stasinopolous, 2004; Verhagen *et al.*, 2004; Baltaci & Kohl, 2003). A single limb stance test as was advocated by Trojian and McKeag (2006) was used in the test battery to evaluate proprioception for inclusion in the prediction model, based on ease of administration and the minimal equipment needs. This test was proven to be a good predictor of ankle injuries on its own, without the need for further costly and complicated balance tests to be administered (McGuine *et al.*, 2000; Cimbiz and Bayazit, 2004).

Generally there is a limited amount of literature concerning the influence of plyometric strength on injuries and even less literature on the possible predictive abilities of plyometric strength testing. This study aimed to enhance literature in this area, based on the fact that Serfontein (2006) presented findings that plyometric ratios could be used in a schoolboy rugby setting to predict injury. This research would help to further investigate these plyometric ratios and to determine whether it could also be used for injury prediction in youth soccer players. . Certain tests were also excluded from the battery and deemed inappropriate based on the literature review, highly skilled nature and excessive costs. These tests included isometric muscle testing of

Quadriceps and Hamstring strength ratios and VMO:VL strength ratios as tested with EMG equipment.

7.3 CONCLUSIONS OF EMPIRICAL RESEARCH

This study succeeded in creating a physical profile of a selected group of South African youth soccer players. This profile contained data on the biomechanical profile, the plyometric strength profile and balance and proprioceptive test data of youth soccer players. There was also data on a complete epidemiological profile of youth soccer players as compiled from data collected from school and club players over a two season period. The physical profile and epidemiological data was combined to create a prediction equation for the occurrence of non contact soccer injuries amongst youth players using logistical regression statistics. A prediction model for groin injuries was also created, which can be combined with the injury equation for the exclusion of groin injuries.

7.3.1 PHYSICAL PROFILING

Objective 1: Creating a physical profile and comparison of school and club youth soccer players.

7.3.1.1 Physical Profile of School Players

There were a total of 49 school soccer players taking part in the research study. The average age of the school players was 16.14 years. 87.8% of the players were right limb dominant, with between 59.6% and 63.8% of players failing a single limb stance test. The performance in the left leg stance test was better than the right leg. The mean bilateral jump height was 27.98cm, with a non-dominant leg jump height of 14.7cm

and a dominant leg jump height of 15.35cm. The non-dominant leg of school players performed better with balance. If the level of skill is taken into account, school players play predominantly with their dominant legs during matches and training. This higher level of right (dominant) leg kicking in school players leads to the left leg being in a supportive stance more often, probably leading to increased balance of non dominant legs. The biomechanical description of the average school player for the lower leg area would be a player with dysfunctional toe position, normal Achilles tendon suppleness; a normal or low foot arch; normal forefoot position; a normal or pronated rear foot; a normal or hypomobile mid-foot joint and a normal or dysfunctional transverse arch. The school player will also probably not have had a previous injury and will show an average lower leg dysfunction score of 4.59 for the left side and 4.55 for the right side. The knee area profile was described as follows: The player had a normal Q-angle, no patella squint, normal patella tilt, normal visual VMO:VL ratio, no history of previous injury to the knee area; a degree of tightness of the quadriceps muscle and a 57.1% possibility of a knee height difference. The profile for the hip area described players with dysfunctional, decreased Hip external rotation and reduced Gluteal muscle length. The player had normal Hip internal rotation and no previous injuries. Between 24.5% and 42.9% of players will also exhibited shortened ITB, Iliopsoas and Adductor muscles, although, these were in the minority. The Lumbo-pelvic profile for the average school player was described as follows: A player would present with Pelvic Bilateral dysfunction, indicating an excessive anterior pelvic tilt. Players also had an excessive lumbar lordosis, as was indicated by the Lumbar coronal view. Players would have normal Lumbar rotation and Extension and 49% of players would also present with decreased lumbar flexion. Between 22.4% and 29.2% of players would also present with SIJ dysfunction (Leg length,

ASIS, PSIS, Rami, Cleft and Sacral rhythm combined) and abnormal Lumbar saggital view (scoliosis). In the neurodynamic area, the profile could be summarised as follows: 49% of players exhibited dysfunction and decreased Straight Leg Raise values. Between 20.4% and 30.6% of players also presented with dysfunctional Prone Knee Bend and Slump neurodynamic tests. The combined neural dysfunction score mean values of 1.020 indicated that 51% of players exhibited some level of dysfunction in the neurodynamic area. The total combined dysfunction score for school players had mean values of 15.22 for the left side and 15.25 for the right side.

7.3.1.2 Physical Profile of Club Players

There were 61 club youth players from three teams involved in this research project. The average age of the players was 16.97 years. Between 67.2% and 70.5% of the players failed a single limb stance test, with mean values of 1.705 and 1.672 for left and right sides. 80.3% of players were right limb dominant and the balance tests indicate that the dominant legs had better balance than the non-dominant legs. The mean bilateral leg jump height was 38.23cm, with the dominant leg jump height of 28.18cm and a non-dominant leg jump height of 28.80cm. Based on the biomechanical analysis of the lower leg area, the average club player presented with decreased Achilles Tendon suppleness, a normal or flat medial foot arch, a normal or hypomobile mid-foot joint and a normal or pronated rear foot. Between 36.1% and 68.9% of players also presented with forefoot positional dysfunction, transverse arch dysfunction and toe positional dysfunction. The average player also had not had any previous injuries. The profile for the knee area showed the average player presenting with decreased length of the quadriceps muscles, a normal Q-angle, patella tilt, knee height, VMO:VL muscle ratio and no previous injuries to the knee area. Between

54.1% and 65.6% of players presented with abnormal patella squinting. The mean dysfunction scores of 2.016 for the left side and 2.295 for the right side indicated relatively little dysfunction in club players for the knee area, with a maximum score of 8 possible for the area. The hip area profile showed players with hip external rotation and right ITB dysfunction, no previous injury and normal hip internal rotation. Between 49.18% and 60.66% also exhibited dysfunction with the Gluteal muscle length tests, Iliopsoas length tests, adductor length test en left leg ITB length tests. The mean dysfunction score for the area was 4.066 for the left side and 4.656 for the right side. For the Lumbo-pelvic area, the average player presented with an excessive anterior pelvic tilt, normal side flexion, normal rotation, normal Thoraco Lumbar fascia length, normal sagittal view with no scoliosis and normal lumbar extension. Between 40.98% and 63.93% of players also presented with leg length differences; ASIS, PSIS, Cleft and Rami asymmetry; an abnormal sacral rhythm; decreased lumbar flexion and an abnormal lumbar coronal view. The combined dysfunction score for the lumbo-pelvic area was 6.016 for the left side and 5.918 for the right side. The neurodynamic area for club players presented the average club player to have decreased prone knee bend test ROM. The results for the slump test were normal and 39.34% of players presented with a decreased Straight Leg Raise test ROM for the left side. The neurodynamic dysfunction score was 1.705 for the left side and 1.787 for the right side. This score was calculated out of a maximum of 6. The combined total dysfunction score for the club players was 18.590 for the left side and 20.049 for the right side. This score is calculated out of a maximum of 58, indicating an average dysfunction of approximately 33% present in players.

7.3.1.3 Physical Profile of Youth Players

There were 110 youth players (combination of school and club players) involved in the research study from seven teams and four different age groups. The average age of the players was 16.6 years, with 83.6% of players being right limb dominant. 65.7% of players failed a single limb stance test. The mean jump height for both legs combined was 33.77cm, with mean heights of 22.60cm for dominant leg jump and 22.66cm for the non dominant leg. The mean D+ND/Bil ratio was 1.311 with a mean D/Bil ratio of 0.656 and a mean ND/Bil ratio of 0.655.

In the biomechanical evaluation of the lower leg and foot area, the average youth player presented with adaptation of toes, normal or flat medial foot arches, a normal or pronated rear foot in standing and lying, and a normal or hypomobile mid-foot joint. Between 42.7% and 51.8% of players also presenting with decreased Achilles tendon suppleness and callusing of the transverse foot arch. This corresponds with the foot profile of a decreased medial arch with associated rear foot pronation and decreased mid-foot mobility. The profile of the knee area indicated that the players presented with excessive tightness of the quadriceps muscles, normal patella tilt and squint, normal knee height, normal Q-angle, a normal VMO:VL ratio and no previous injuries. In the hip area, there was shortening of hip external rotators, decreased Gluteal muscles length, normal hip internal rotation and no previous history of injury. Between 38.2% and 62.7% of players also presented with shortened muscle length of the adductor and Iliopsoas muscles and decreased ITB length. The mean hip area dysfunction scores for youth players are 3.518 for the left side and 3.864 for the right side. The profile for the Lumbo-pelvic area could be described as follows: There was an excessive anterior tilt of the pelvis with normal lumbar extension, side flexion,

rotation and lumbar sagittal view without presence of scoliosis. Between 58.18% and 65.45% of players presented with an abnormal coronal view and decreased lumbar flexion. Between 41.81% and 44.54% of players also presented with leg length, ASIS, PSIS, Cleft, Rami and sacral rhythm asymmetry. The similarity of the results for these tests in all players contributed to a new variable called 'SIJ dysfunction' to be formed from the average of the scores for ASIS, PSIS, Cleft, Rami and Sacral rhythm. The neurodynamic results indicated that between 44.54% and 50.91% of players presented with decreased Straight leg raise and Prone knee bend tests. The total dysfunction score for the left and right sides were 17.091 and 17.909 respectively, indicating that there were higher levels of dysfunction on the right side than the left.

The aim of objective 1 was the creation of a physical profile and comparison of school and club youth soccer players. A comprehensive physical profile of a selected group South African youth players was compiled, which included school and club players, and comparisons were made between the different player age groups and between club and school players, attaining objective 1. These profiles can be used for comparative purposes in future research on school and club soccer players.

7.3.2 INJURY EPIDEMIOLOGY

Objective 2: Recording an epidemiological profile of youth soccer injuries over a two season period.

7.3.2.1 Epidemiology of School Players

School players presented with injury rates of 20.66 injuries/1000 match hours, 13.82 injuries/1000 training hours and a combined total of 16.41 injuries/1000 playing

hours. The school injury rates fall within the ranges reported by previous research (Le Gall *et al.*, 2006; Schmidt-Olsen *et al.*, 1991; Emery & Meeuwisse; 2006), although research by Junge *et al.* (2004) showed higher injury rates. The percentage of lower limb injuries was 76.19% of the total injuries. This is lower than the percentages reported by Price *et al.* (2004), Deehan *et al.* (2007) and Junge *et al.* (2004), but higher than the percentages reported by Le Gall *et al.* (2006) and Schmidt-Olsen *et al.* (1991). The ankle, knee and lower leg were the areas with the highest percentage of injuries, with 23.81%, 19.05% and 19.05% of the total injuries respectively. This is similar to the findings of Schmidt-Olsen *et al.* (1991) which also showed the ankle (23.1%), knee (26%) and lower leg (10.9%) to be the most injured areas. Contusions (47.62% of total), sprains (19.05% of total) and overuse (19.05% of total) were the types of injuries with the highest occurrence rate. Only 38.1% of injuries were non-contact injuries with 61.9% of injuries being contact injuries. Emery and Meeuwisse (2006) showed much higher figures, with 54% of injuries being non-contact. Deehan *et al.* (2007) also had nearly double the non-contact injury percentage with 69%. Price *et al.* (2004) reported a more similar percentage with 34% as non contact injuries. High contact injury rates are usually associated with high percentages of contusion injuries. The lower percentage of non-contact injuries correlate well with the biomechanical evaluation results, where school players presented with a less dysfunctional profile than club players. 90.48% of injuries incurred by school players had a severity that led to less than a week absence from play. 57.14% of these injuries resulted in no play missed.

7.3.2.2 Epidemiology of Club Players

Club players have injury rates (Total rate=11.5/1000 player hours, Training rate=6.13/1000 training hours, Match rate= 45.80/1000 match hours) that fall within rates of previous research on youth players (Price *et al.*, 2004; Deehan *et al.*, 2007; Le Gall *et al.*, 2006; Schmidt-Olsen *et al.*, 1991; Junge *et al.*, 2004). The percentage of lower limb injuries was 91.1% of total, with the ankle (26.5% of total), knee (20.2% of total) and thigh (17.7% of total) being the most injured anatomical areas. 83.5% of injuries were relatively minor, with absences of less than one week. Of all injuries, 1.2% was classified as major injuries that led to more than 28 days of absence from play. The mechanism of injuries showed that sprains (34.2%), strains (31.6%) and contusions (22.8%) were the most common types of injuries amongst the players. Price *et al.* (2004) reported 31% of injuries being strains, 20% being sprains and 8% being contusions. Deehan *et al.* (2007) reported 37% of injuries as strains, 18% as sprains and only 5.8% as muscular contusions. Junge *et al.* (2004) reported 31.8% of injuries as strains, 20.3% as sprains and 28.4% as contusions. It can be seen from most of the previous research that sprains, strains and contusions amount for the largest percentage of injuries amongst youth players. Of the total injuries, 57% were non contact injuries, with 8.9% of all injuries being overuse injuries.

7.3.2.3 Epidemiology of Youth Players

In the epidemiological study on youth players, there were a total of 49 training injuries and 52 match injuries. The total injury rate for youth players was 12.27 injuries/1000 hours, with a total match injury rate of 37.12 injuries/1000 match hours. The combined training injury rate was 7.17 injuries/1000 training hours. 87.13% of injuries were of the lower limb area and the individual areas with the highest

percentage of injuries were the ankle (25.74%), Knee (19.80%), Thigh (15.84%) and lower leg (14.85%). The totals for youth players indicate sprains (30.69% of total), strains (27.72% of total) and contusions (27.72% of total) to be the most common mechanism of injuries. The severity of injuries show 'zero day' injuries to be the most common type (35.64%), followed by 'slight' (33.66%) and 'minor' (14.85%). School players had higher injury rates than club players but the severity of injuries to club players was higher, with longer absences from play. Non-contact injuries accounted for 52.47% of the total with 46.53% being contact injuries.

Objective 2 was aimed at the recording of an epidemiological profile of youth soccer injuries over a two season period. This epidemiological profile contained data on school as well as club players and was also compared to previous youth epidemiological research. The data was also collected in a manner prescribed by Fuller *et al.* (2006) in an effort to standardise football (soccer) epidemiological research. When compared to previous South African literature, this is the first comprehensive epidemiological profile of South African youth soccer injuries which included both school and club players for training and matches of an entire season, thus achieving successful completion of objective 2.

7.3.3 CREATION OF PREDICTION MODEL

Objective 3: To create a statistical predictive equation combining biomechanics, balance and proprioception, plyometric strength ratios of ND/Bil (Non dominant leg plyometrics/ Bilateral plyometrics), D/Bil (Dominant leg plyometrics/ Bilateral plyometrics) and ND+D/Bil (Non dominant leg + dominant leg plyometrics/ Bilateral

plyometrics) and previous injuries to determine a youth soccer player's risk of the occurrence of lower extremity injuries.

A cluster analysis of the Statistica software (STATSOFT, Inc., 2004) was used to decrease the number of variables that were considered for inclusion in the prediction model. The next step in the creation of a prediction model was to identify the variables that discriminate best between injured and non-injured players. This was done by using a stepwise logistic regression analysis. After the analysis, ten variables with the largest odds ratios were selected for inclusion in the prediction model to predict non contact injuries in youth soccer players. The prediction model created from the stepwise analysis presents as follows:

$$P(\text{injury}) = \frac{\exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}{1 + \exp(-8.2483 - 1.2993a + 1.8418b + 0.2485c + 4.2850d + 1.3845e + 1.3004f - 1.1566g + 1.8273h - 0.9460i - 0.5193j)}$$

a = Toe dysfunction

b = Previous ankle injury

c = Ankle dysfunction

d = SIJ dysfunction

e = Lumbar extension

f = Straight leg raise

g = Psoas length

h = Patella squint

i = Gluteal muscle length

j = Lumbar dysfunction

P = probability of non contact injury

$\exp(x) = e^x$, with e the constant 2.7183

In the ankle area, the toe positional test, previous ankle injury history and combined ankle dysfunction score was included in the prediction model. In the knee area, the patella squint test was included in the model. In the hip area, the Psoas component of the Thomas test was included, along with the Gluteal muscle length test. In the lumbo-pelvis area, the SIJ dysfunction (average of Leg length, ASIS, PSIS, Rami, Cleft and Sacral rhythm tests), lumbar extension test and lumbar dysfunction scores

were included in the prediction model. In the neurodynamic area, the Straight leg raise test was included in the prediction model. The prediction model thus contains tests from all five the biomechanical areas of the body.

The I value of the prediction model ($I=0.67$), along with the sensitivity (65.52%), specificity (94.87%), overall correct percentage of prediction (86.91%) and Hosmer and Lemeshow interferential goodness-to-fit value ($X^2(8)$ of 0.7204), all show this prediction model to be a valid and accurate prediction tool for non contact youth soccer injuries.

A second prediction model, for the prediction of hip and groin injuries, was also created using logistical regression statistics. This model presents as follows:

$$P(\text{Groin injury}) = \frac{\exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}{1 + \exp(-116.2 + 33.5383d + 14.5108k + 4.1972m + 1.9330e + 10.7006f - 14.4028n + 48.8751p)}$$

d = SIJ dysfunction

k = Previous knee injury

m = Previous hip injury

e = Lumbar extension

f = Straight leg raise

n = Limb dominance

p = ND/Bil plyometric ratio

P = probability of groin injury

$\exp(x) = e^x$, with e the constant 2.7183

The prediction model for hip and groin injuries include the variables of SIJ dysfunction, previous knee injury, previous hip injury, lumbar extension, straight leg raise, dominance and the ratio of non-dominant leg to bilateral legs plyometric height.

There were 107 observations taken into account for the creation of the model, which ultimately contained seven predictors.

When all the validifying tests are examined, the I-value (0.65), sensitivity (66.67%), specificity (98.01%), false negatives (1.98%), false positives (33.33%), Hosmer and Lemeshow goodness-to-fit value ($X^2(8) = 0.77$) and the overall percentage of correct prediction (96.26%) all show that this model is an accurate prediction tool for hip and groin injuries amongst youth soccer players.

Using the hip and groin prediction model, combined with the injury prediction model, injuries in youth soccer players can be predicted. The data for each player should first be substituted into the injury prediction model, to determine the chance of injury during the season. The data should then be substituted into the hip and groin injury prediction model, determining the chance of hip and groin injuries during the season. The results from the groin injury prediction model could then be used to exclude groin injuries amongst players. A negative result for the hip and groin injury, which showed a false negative percentage of 1.98%, could be used to determine that an injury that was predicted using the overall injury prediction model, would not be a hip and groin injury. The prehabilitation programme could then be adapted to focus on areas other than the hip and groin area.

7.3.4 PREVENTATIVE TRAINING PROGRAMME

Objective 4: The creation of a preventative training programme for youth soccer players, addressing physical shortcomings identified with the prediction model.

A preventative training programme will be created to address the shortcomings identified with the two injury prediction models. The areas that will be addressed with the training programme are the following: Foot dysfunction, SIJ dysfunction, Lumbar

extension, Straight leg raise, Hip flexor muscle length, patella squint, Gluteal muscle length, lumbo pelvic dysfunction and plyometric exercises. These areas are addressed based on their identification for inclusion in the injury prediction models. Certain parameters identified by the prediction models cannot be addressed by a training programme. These include: previous knee injury, previous hip injury, limb dominance and previous ankle injury. The different exercises can be seen in Annexure E.

Exercises addressing foot dysfunction include toe curl, toe marble pick up and towel scrunch addressing intrinsic foot muscle strength. Increased foot intrinsic muscle strength help to support the longitudinal foot arches, leading to decreased flattening of the foot arches during gait. There are also stretches for the gastrocnemius and soleus muscles, increasing Achilles tendon suppleness. Toe dysfunction is often a result of excessive tightness of the hip lateral rotators, causing external rotation of the feet, leading to toe adaptation during gait. Stretches of the hip lateral rotators will address this excessive external rotation and will decrease toe adaptation. Another measure to be considered for decreased foot dysfunction is arch supporting inner soles. These soles will support flat foot arches in a raised position, decreasing rear foot pronation in the process.

SIJ dysfunction is another important problem that needs to be addressed. Sacro-iliac joint mal-alignment should be addressed by joint mobilisation, manipulation or muscle energy techniques. Following the correction of the asymmetry, the core muscles should be strengthened to keep the symmetrical alignment of the Sacro-iliac joint. Strong core muscles (Transverse abdominus, oblique abdominus, pelvic floor, and multifidi muscles) help to keep the pelvis correctly aligned and also help to re-

align it, should it become asymmetrical during play. The core exercises included are: bridging with leg extension, straight leg raise with abduction, body bridge with raised leg, cycling on back, side bridging, four point kneel with bridging and static abdominals.

Lumbar extension is addressed through stretching of the lumbar flexors and also the iliopsoas muscle, of which the iliacus portion attaches to the lumbar spine. The stretches included for this area include a lumbar extension stretch and an iliopsoas stretch.

The straight leg raise from the neurodynamic area are also included in the prediction model. Decreased straight leg raise is addressed with the straight leg raise neural mobilisation and the straight leg raise neural stretch, which are shown in Annexure D.

Hip flexor muscle length is addressed by an iliopsoas stretch and an iliopsoas stretch with a bench.

Abnormal patella squint needs to be addressed by strengthening the Vastus Medialis Oblique muscle, which will then help to re-align the patella into a more horizontal plane. The VMO exercises included in the programme are: straight leg raise, terminal knee extension, seated straight leg raise and an eccentric step down exercise.

Gluteal muscle length are addressed by two different gluteal muscle stretches and a piriformis stretch.

Lumbo-pelvic dysfunction is also addressed in the training programme. SIJ dysfunction was already discussed with core strengthening exercises. Lumbar side flexion and rotation is also addressed in this area, along with lumbar flexion. Lumbar extension was also discussed earlier. The coronal view and pelvic bilateral position would also be addressed by lumbar flexion stretches. The exercises included for this area are: Lumbar rotation, Thoraco Lumbar fascia stretch, kneeling, standing and seated lumbar flexion stretches and lumbar side flexion stretches.

Plyometric exercises are included to address the ND/Bil variable that was included in the Groin injury prediction model. The exercises included in the programme are aimed at addressing unilateral jumping activities, as these will improve the ratio of ND/Bil to a larger extent than bilateral jumping exercises.

The variables that cannot be addressed by the training programme include previous knee injury, previous hip injury, previous ankle injury and limb dominance. As one can have no control over previous injuries, the only option is to rehabilitate injuries sufficiently when they do occur, and trying to prevent them with training based on the overall injury prediction model. Proper rehabilitation would help to reduce re-occurrence of these injuries. Limb dominance cannot be addressed, except by possibly focusing on getting players to be more ambidextrous during football skills training sessions.

The programme is designed with a pre-season and an in-season component, as different training regimes are followed during these periods. The preventative programme follows:

Pre season Programme:

(All exercises are illustrated and explained in Annexure E)

Stretches: (To be done daily)

Soleus stretch

Calf stretch

Lumbar extension stretch

Iliopsoas stretch or Iliopsoas stretch with bench

Straight leg raise neural mobilisation

Straight leg raise neural stretch

Gluteal muscle stretch

Piriformis stretch

Seated, kneeling or standing lumbar flexion stretch

Thoraco Lumbar fascia stretch

Side flexion stretch

Exercises: (To be done every second day)

Lumbar rotation

Foot intrinsic exercises: Any two of the three exercises in Annexure E

Core exercises: Any three of the exercises in Annexure E

VMO exercises: Any three of the four exercises in Annexure E

Plyometric exercises: Any four of the nine plyometric exercises in Annexure E

In-season Programme:

Stretches: (To be done three times a week)

Soleus stretch

Calf stretch

Lumbar extension stretch

Iliopsoas stretch or Iliopsoas stretch with bench

Straight leg raise neural mobilisation

Straight leg raise neural stretch

Gluteal muscle stretch

Piriformis stretch

Seated, kneeling or standing lumbar flexion stretch

Thoraco Lumbar fascia stretch

Side flexion stretch

Exercises: (To be done twice a week)

Lumbar rotation

Foot intrinsic exercises: Any two of the three exercises in Annexure E

Core exercises: Any three of the exercises in Annexure E

VMO exercises: Any three of the four exercises in Annexure E

Plyometric exercises: Any four of the nine plyometric exercises in Annexure E

7.4 RECOMMENDATIONS

This research has recorded a physical profile for school, club and youth players, which should be consulted when future research is carried out on South African youth soccer players. The epidemiological data should be used for comparative purposes in future epidemiological research on South African youth players. The prediction models and training programme should be implemented at youth level by South African schools and youth clubs, to help with the identification of players at risk of non contact injuries and the prevention of these injuries.

Pre-season testing using the test battery should be conducted at the start of the pre-season period. Players with an increased risk of injury should use the pre-season programme for the duration of the pre-season period. Other players should start with the in-season training programme during the pre-season period. All players should then switch to the prescribed in-season training programme when the competitive season starts. These programmes should not replace any training programmes followed normally during the pre-season period, but should supplement these programmes.

7.4.1 Shortcomings of the study

This study succeeded in creating a physical profile of a selected representative group of South African youth soccer players, while also recording an injury epidemiological profile of these players over a two year period. Norm scales were also created for injury epidemiology and the physical profile of youth, club and school soccer players. This data is of vital importance for future research. The prediction models and preventative training programme are also of great importance in the fight to reduce injuries in youth soccer. During the research, the following shortcomings were identified:

- 1) The relatively small sample sizes made the creation of prediction models for individual anatomical areas and individual age groups impossible, due to the low number of recorded injuries. The sample size also caused the data for left and right sided testing to have to be combined for the purposes of creating the prediction models.
- 2) Due to financial constraints, isometric quadriceps and hamstring testing, along with EMG testing of VMO:VL ratios, could not be included in the research.

7.4.2 Recommendations for Future Research

- 1) The research should be repeated on a larger sample group in order to determine whether prediction models for individual age groups could be created, and whether the same prediction functions are created. There should also be attempts to create prediction models for individual anatomical areas using this larger sample group.
- 2) The research should be repeated on senior soccer players, to determine whether the models would prove effective for senior players, or whether different variables would be included for senior players.
- 3) Isometric muscle testing and EMG studies of VMO:VL ratios should be included in future studies to further refine the prediction models.
- 4) The norm scales that were created should be used for comparative purposes for future research on South African youth soccer players.
- 5) The injury prevention programmes remains untested, and the effectiveness of the programme on injury levels should be investigated.

In summary, this study conducted a proprioceptive, biomechanical, plyometric and injury epidemiological study on youth soccer players. A physical and epidemiological profile was created for youth soccer players and this profile was used in the creation of an overall injury prediction model as well as a prediction model for hip and groin injuries. The efficacy of this model was tested and it proved an acceptably accurate prediction tool for non-contact youth soccer injuries.

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ANNEXURE A

INFORMED CONSENT FORM

I will be commencing a PhD in Movement Education at the North West University in 2007. I hereby request your consent for the participation of your son in this study. It should cause minimal interference with players and staff and will benefit the school, the scientific- and soccer playing communities alike.

My thesis research project will be aimed at creating a soccer injury prediction model for youth soccer players. The research will entail the following:

1. Teams participating in the study will be the U/16 and U/18 soccer teams.
2. At the beginning of the season players will be given a biomechanical evaluation and plyometric and balance testing will be done.
3. During the season a register will be kept by the coach of each team to indicate the amount of hours each player was involved in match play or training.
4. All injuries occurred by players during the season will be assessed on an ongoing basis by a well qualified Physiotherapist at free weekly clinics at the school throughout the season, and these injuries will be documented.
5. At the end of the season, statistical methods will be used to create a mathematical injury prediction model using the test data and the data from injury clinics.

No player will be negatively affected by any part of the study. A full briefing and explanation will be given to all coaches and players involved in the study. Testing will be conducted at the school.

The aim of this study is to create a soccer injury prediction model for youth soccer players, with the aim of preventing these injuries in future.

JH Serfontein

I, _____ parent/legal guardian of _____
 _____ hereby give consent that my son may participate in this study.

Signature: _____ Date: _____

ANNEXURE B

BIOMECHANICAL EVALUATION FORM

FOOT AND LOWER LEG	L	R	DESCRIPTION
TA SUPPLENESS TEST			1:20° + / 2:10° - 20° / 3:10° -
FOOT LONGITUDINAL TEST			
High Arch			1:No High Arch / 2: High Arch
Low Arch			1:No Low Arch / 2: Low Arch
FORE FOOT			1:Normal / 2:Anomalies
REAR FOOT STANDING TEST			
Pronation			1:No Pronation / 2: Pronated Foot
Supination			1:No Supination / 2: Supinated Foot
REAR FOOT LYING TEST			
Pronation			1:No Pronation / 2: Pronated Foot
Supination			1:No Supination / 2: Supinated Foot
TRANSVERSE ARCH			1:Normal / 2:Flat
MIDFOOT MOBILITY TEST			
Hypomobility			1:No Hypomobility / 2: Hypomobile Joint
Hypermobility			1:No Hypermobility / 2: Hypermobile Joint
TOES			1:Normal / 2:Anomalies
PREVIOUS INJURY			1:No injury / 2:Previous injury
KNEE			
THOMAS TEST: QUADS			1:70° + / 2:50° - 70° / 3:50° -
KNEE Q-ANGLE			1:9° - / 2:9° +
PATELLA SQUINT			1:9° - / 2:9° +
PATELLA TILT			1:0° - / 2:0° +
KNEE HEIGHT			1:Normal / 2:Anomalies
VMO			1:Normal / 2:Anomalies
PREVIOUS INJURY			1:No Injuries / 2:Previous Injuries
HIP			
ITB			1:Neutral / 2: 0° - 10° / 3:10° - 30°
ILIOPSOAS			1:30° + / 2:15° - 30° / 3:15° -
GLUTEAL MUSCLES			1:120° + / 2:90° - 120° / 3:90° -
ADDUCTOR LENGTH			1:120°+ / 2:100°-120° / 3:100°-
HIP INTERNAL ROTATION			1:30° + / 2:15° - 30° / 3:15° -
HIP EXTERNAL ROTATION			1:90° + / 2:60° - 90° / 3:60° -
PREVIOUS INJURY			1:No Injuries / 2:Previous Injuries
LUMBO PELVIC AREA			
LEG LENGTH			1:L=R / 2:1cm discrepancy / 3:1cm+ discrepancy
ASIS			1:L=R / 2:Discrepancy
PSIS			1:L=R / 2:Discrepancy
RAMI			1:L=R / 2:Discrepancy
CLEFT			1:L=R / 2:Discrepancy
PELVIS BILATERAL POSITION			1:2-3cm / 2:3-5cm / 3:5cm+
THORACO LUMBAR FASCIA			1:1cm / 2:1-3cm / 3:3cm+
SACRUM RHYTHM			1:L=R / 2:Aberrant
EXTENSION			1:<2cm / 2: 2-3cm / 3: 3cm+
FLEXION			1:Easy ROM / 2:Limited ROM / 3:Very Limited ROM
ROTATION			1:Easy ROM / 2:Limited ROM / 3: Very Limited ROM
SIDE FLEXION			1:Easy ROM / 2:Limited ROM / 3: Very Limited ROM
LUMBAR CORONAL			1:Normal / 2:Anomalies
LUMBAR SAGGITAL			1:Normal / 2:Anomalies
NEURODYNAMICS			
STRAIGHT LEG RAISE			1:90° / 2:70°- 90° / 3:70°-
PRONE KNEE BEND			1:Full ROM No tension / 2:Full ROM With tension / 3:No touching
SLUMP			1:Full ROM No tension / 2:Full ROM With tension / 3:No touching

ANNEXURE C

INJURY REPORT FORM

CLINIC DATE: _____

NAME: _____

SCHOOL: _____

POSITION: _____ AGE GROUP: _____

SITE OF INJURY (Circle) Head/Face, Neck, Shoulder, UArm, Elbow, LArm, Wrist,
 Hand/Finger/Thumb, Sternum/Ribs/UBack, LBack/Pelvis/Sacrum, Hip/Groin, Thigh, Knee, Lower
 leg/TA, Ankle, Foot/Toe, Other _____

SEVERITY OF INJURY Zero Day, Slight (1-3), Minor (4-7), Mild (7-14), Moderate (14-28),
 Major (28+)

MECHANISM: Contact/ Non Contact

IF CONTACT: With ball/ Other player / Other object _____

WHERE: Match / Training

TYPE: Sprain, Strain, Contusion, Fracture, Dislocation, Overuse, Other _____

IF MATCH INJURY:

Time of game: 1st Half / 2nd Half

Play: Legal / Illegal

If illegal: Free kick/ Yellow Card/ Red Card to: Player/Opponent

CLASSIFICATION OF INJURY

Diagnosis: _____

Assessment: _____

SIJ (In case of Thigh/Back/Groin): Symmetrical/ Asymmetrical

Treatment: _____

Instructions to Coach/ Player _____

Special Tests/ Referrals _____

ANNEXURE D.1

Descriptive statistics for age dominance, proprioception and plyometric results of U/16 school soccer players

Number	Milner U/16				St Conrad's U/16			
	13				15			
	Mean		Std Dev		Mean		Std Dev	
AGE:	15.615		0.510		14.667		0.720	
RIGHT LIMB DOMINANCE %	76.9		44.0		1.933		0.260	
BALANCE	Mean L	Std Dev	Mean R	Std Dev	Mean L	Std Dev	Mean R	Std Dev
Single Limb Stance	1.692	0.480	1.846	0.380	1.500	0.520	1.571	0.510
PLYOMETRICS	Mean		Std Dev		Mean		Std Dev	
Bilateral (cm)	27.277		4.960		26.057		5.560	
Dominant (cm)	15.138		3.450		14.150		4.010	
Non-Dominant (cm)	14.462		3.020		13.257		3.140	
D+ND/Bil	1.094		0.160		1.044		0.110	
D/Bil	0.558		0.090		0.537		0.080	
ND/Bil	0.536		0.100		0.507		0.050	

ANNEXURE D.2

Descriptive statistics for foot and lower leg biomechanical results of U/16 school soccer players

FOOT AND LOWER LEG	Milner U/16				St Conrad's U/16			
	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
ACHILLES TENDON SUPPLENESS TEST	1.000	0.000	1.000	0.000	1.133	0.350	1.133	0.350
FOOT LONGITUDINAL TEST								
High Arch	1.000	0.000	1.000	0.000	1.067	0.260	1.067	0.260
Low Arch	1.538	0.520	1.462	0.520	1.600	0.510	1.600	0.510
FORE FOOT	1.385	0.510	1.385	0.510	1.600	0.510	1.600	0.510
REAR FOOT STANDING TEST								
Pronation	1.923	0.280	1.923	0.280	1.333	0.490	1.333	0.490
Supination	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
REAR FOOT LYING TEST								
Pronation	1.923	0.280	1.923	0.280	1.333	0.490	1.333	0.490
Supination	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
TRANSVERSE ARCH	1.462	0.520	1.462	0.520	1.533	0.520	1.533	0.520
MID-FOOT MOBILITY TEST								
Hypomobility	1.538	0.520	1.462	0.520	1.600	0.510	1.600	0.510
Hypermobility	1.000	0.000	1.000	0.000	1.067	0.260	1.067	0.260
TOES	2.000	0.000	2.000	0.000	1.800	0.410	1.800	0.410
PREVIOUS INJURY	1.154	0.380	1.077	0.280	1.000	0.000	1.067	0.260
DYSFUNCTION SCORE /10	4.846	1.340	4.615	1.390	4.067	1.620	4.133	1.640

ANNEXURE D.3

Descriptive statistics for knee area biomechanical results of U/16 school soccer players

KNEE	Milner U/16				St Conrad's U/16			
	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
THOMAS TEST: QUADS	1.308	0.480	1.308	0.480	1.333	0.490	1.333	0.490
KNEE Q-ANGLE	1.077	0.280	1.077	0.280	1.133	0.350	1.133	0.350
PATELLA SQUINT	1.077	0.280	1.077	0.280	1.133	0.350	1.133	0.350
PATELLA TILT	1.385	0.510	1.385	0.510	1.400	0.510	1.400	0.510
KNEE HEIGHT	1.538	0.520	1.538	0.520	1.600	0.510	1.600	0.510
VMO	1.000	0.000	1.000	0.000	1.133	0.350	1.133	0.350
PREVIOUS INJURY	1.077	0.280	1.077	0.280	1.000	0.000	1.133	0.350
DYSFUNCTION SCORE /8	1.462	1.270	1.462	1.270	1.733	1.620	1.867	1.680

ANNEXURE D.4**Descriptive statistics for hip area biomechanical results of U/16 school soccer players**

	Milner U/16				St Conrad's U/16			
HIP	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
ITB	1.077	0.280	1.154	0.380	1.733	0.460	1.733	0.460
ILIOPSOAS	1.231	0.600	1.231	0.600	1.533	0.520	1.533	0.520
GLUTEAL MUSCLES	1.846	0.380	1.923	0.490	2.000	0.380	1.933	0.460
ADDUCTOR LENGTH	1.385			0.510	1.200			0.410
HIP INTERNAL ROTATION	1.000	0.000	1.000	0.000	1.067	0.260	1.067	0.260
HIP EXTERNAL ROTATION	1.846	0.380	1.923	0.490	1.800	0.560	1.733	0.590
PREVIOUS INJURY	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
DYSFUNCTION SCORE /13	2.385	1.450	2.615	1.710	3.333	1.180	3.200	1.210

ANNEXURE D.5

Descriptive statistics for lumbo-pelvic area biomechanical results of U/16 school soccer players

LUMBO PELVIC AREA	Milner U/16				St Conrad's U/16			
	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
LEG LENGTH	1.308			0.480	1.267			0.460
ASIS	1.231			0.440	1.267			0.460
PSIS	1.231			0.440	1.267			0.460
RAMI	1.231			0.440	1.267			0.460
CLEFT	1.231			0.440	1.267			0.460
PELVIS BILATERAL POSITION	1.923			0.280	2.000			0.000
THORACO LUMBAR FASCIA	1.385	0.510	1.385	0.510	1.533	0.520	1.533	0.520
SACRUM RHYTHM	1.154			0.440	1.200			0.460
EXTENSION	1.077			0.280	1.267			0.460
FLEXION	1.308			0.480	1.733			0.590
ROTATION	1.000	0.000	1.000	0.000	1.133	0.350	1.133	0.350
SIDE FLEXION	1.231	0.440	1.231	0.440	1.400	0.510	1.400	0.510
LUMBAR CORONAL	1.923			0.280	1.933			0.260
LUMBAR SAGGITAL	1.308			0.480	1.333			0.490
DYSFUNCTION SCORE /21	4.308	2.780	4.308	2.780	5.533	3.140	5.533	3.140

ANNEXURE D.6

Descriptive statistics for neurodynamic biomechanical results of U/16 school soccer players

	Milner U/16				St Conrad's U/16			
NEURODYNAMICS	L Mean	STD Dev	R Mean	STD Dev	L Mean	STD Dev	R Mean	STD Dev
STRAIGHT LEG RAISE	1.308	0.480	1.308	0.480	1.600	0.510	1.600	0.510
PRONE KNEE BEND	1.154	0.380	1.154	0.380	1.267	0.460	1.267	0.460
SLUMP	1.308	0.480	1.308	0.480	1.400	0.510	1.400	0.510
DYSFUNCTION SCORE /6	0.769	1.240	0.769	1.240	1.267	1.100	1.267	1.100
TOTAL DYSFUNCTION SCORE /58	13.769	4.690	13.769	5.180	15.933	5.890	16.000	5.870

ANNEXURE D.7

Descriptive statistics for age dominance, proprioception and plyometric results of U/18 school soccer players

Number	Milner U/18				St Conrad's U/18			
	14				7			
	Mean		Std Dev		Mean		Std Dev	
AGE:	17.643		0.480		17.286		0.760	
RIGHT LIMB DOMINANCE %	1.857		0.360		2.000		0.000	
BALANCE	Mean L	Std Dev	Mean R	Std Dev	Mean L	Std Dev	Mean R	Std Dev
Single Limb Stance	1.692	0.480	1.615	0.510	1.429	0.530	1.429	0.530
PLYOMETRICS	Mean		Std Dev		Mean		Std Dev	
Bilateral (cm)	29.462		8.130		30.357		4.160	
Dominant (cm)	15.769		4.760		17.357		3.210	
Non-Dominant (cm)	16.331		5.410		14.971		4.690	
D+ND/Bil	1.082		0.110		1.066		0.200	
D/Bil	0.534		0.070		0.574		0.100	
ND/Bil	0.549		0.090		0.493		0.130	

ANNEXURE D.8

Descriptive statistics for foot and lower leg biomechanical results of U/18 school soccer players

	Milner U/18				St Conrad's U/18			
FOOT AND LOWER LEG	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
ACHILLES TENDON SUPPLENESS TEST	1.071	0.270	1.071	0.270	1.286	0.490	1.286	0.490
FOOT LONGITUDINAL TEST								
High Arch	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
Low Arch	1.643	0.500	1.643	0.500	1.714	0.490	1.714	0.490
FORE FOOT	1.143	0.360	1.143	0.360	1.286	0.490	1.286	0.490
REAR FOOT STANDING TEST								
Pronation	1.857	0.360	1.857	0.360	1.571	0.530	1.571	0.530
Supination	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
REAR FOOT LYING TEST								
Pronation	1.929	0.270	1.929	0.270	1.571	0.530	1.571	0.530
Supination	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
TRANSVERSE ARCH	1.429	0.510	1.429	0.510	1.714	0.490	1.714	0.490
MID-FOOT MOBILITY TEST								
Hypomobility	1.714	0.470	1.714	0.470	1.714	0.490	1.714	0.490
Hypermobility	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
TOES	1.929	0.270	1.929	0.270	2.000	0.000	2.000	0.000
PREVIOUS INJURY	1.071	0.270	1.071	0.270	1.143	0.380	1.143	0.380
DYSFUNCTION SCORE /10	4.714	1.380	4.714	1.380	5.000	1.000	5.000	1.000

ANNEXURE D.9

Descriptive statistics for knee area biomechanical results of U/18 school soccer players

KNEE	Milner U/18				St Conrad's U/18			
	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
THOMAS TEST: QUADS	1.429	0.510	1.429	0.510	1.714	0.490	1.714	0.490
KNEE Q-ANGLE	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
PATELLA SQUINT	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
PATELLA TILT	1.286	0.470	1.286	0.470	1.429	0.530	1.429	0.530
KNEE HEIGHT	1.500	0.520	1.500	0.520	1.714	0.490	1.714	0.490
VMO	1.071	0.270	1.071	0.270	1.143	0.380	1.000	0.000
PREVIOUS INJURY	1.214	0.430	1.214	0.430	1.000	0.000	1.000	0.000
DYSFUNCTION SCORE /8	1.500	1.160	1.500	1.160	2.000	0.820	1.857	0.690

ANNEXURE D.10

Descriptive statistics for hip area biomechanical results of U/18 school soccer players

	Milner U/18				St Conrad's U/18			
HIP	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
ITB	1.071	0.270	1.214	0.430	1.714	0.490	1.714	0.490
ILIOPSOAS	1.214	0.430	1.214	0.430	1.286	0.490	1.286	0.490
GLUTEAL MUSCLES	1.929	0.470	1.929	0.470	2.000	0.000	2.000	0.000
ADDUCTOR LENGTH	1.071			0.270	1.429			0.530
HIP INTERNAL ROTATION	1.000	0.000	1.000	0.000	1.143	0.380	1.143	0.380
HIP EXTERNAL ROTATION	1.857	0.530	1.857	0.530	1.857	0.380	1.857	0.380
PREVIOUS INJURY	1.214	0.430	1.143	0.360	1.143	0.380	1.143	0.380
DYSFUNCTION SCORE /13	2.357	1.220	2.429	1.220	3.571	1.400	3.571	1.400

ANNEXURE D.11

Descriptive statistics for lumbo-pelvic area biomechanical results of U/18 school soccer players

LUMBO PELVIC AREA	Milner U/18				St Conrad's U/18			
	L Mean	Std Dev	R Mean	Std Dev	L Mean	Std Dev	R Mean	Std Dev
LEG LENGTH	1.500			0.650	1.143			0.380
ASIS	1.429			0.510	1.143			0.380
PSIS	1.429			0.510	1.143			0.380
RAMI	1.429			0.510	1.143			0.380
CLEFT	1.429			0.510	1.143			0.380
PELVIS BILATERAL POSITION	2.000			0.000	2.000			0.000
THORACO LUMBAR FASCIA	1.357	0.500	1.357	0.500	1.714	0.490	1.714	0.490
SACRUM RHYTHM	1.429			0.510	1.143			0.380
EXTENSION	1.000			0.000	1.143			0.380
FLEXION	1.429			0.510	1.714			0.480
ROTATION	1.000	0.000	1.000	0.000	1.000	0.000	1.000	0.000
SIDE FLEXION	1.071	0.270	1.071	0.270	1.571	0.530	1.571	0.530
LUMBAR CORONAL	2.000			0.000	2.000			0.000
LUMBAR SAGGITAL	1.071			0.270	1.143			0.380
DYSFUNCTION SCORE /21	5.571	3.500	5.571	3.500	5.000	2.710	5.000	2.710

ANNEXURE D.12

Descriptive statistics for neurodynamic biomechanical results of U/18 school soccer players

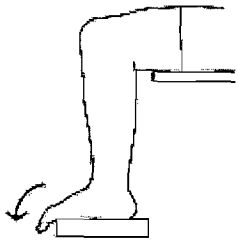
	Milner U/18				St Conrad's U/18			
NEURODYNAMICS	L Mean	STD Dev	R Mean	STD Dev	L Mean	STD Dev	R Mean	STD Dev
STRAIGHT LEG RAISE	1.429	0.510	1.429	0.510	1.714	0.490	1.714	0.490
PRONE KNEE BEND	1.000	0.000	1.000	0.000	1.571	0.530	1.571	0.530
SLUMP	1.000	0.000	1.000	0.000	1.714	0.490	1.714	0.490
DYSFUNCTION SCORE /6	0.427	0.510	0.427	0.510	2.143	1.210	2.143	1.210
TOTAL DYSFUNCTION SCORE /58	14.643	4.090	14.714	4.010	17.714	5.020	17.571	5.060

ANNEXURE E

Training Programme

Exercises addressing Foot dysfunction:

Toe Curl (Intrinsic Foot muscles)

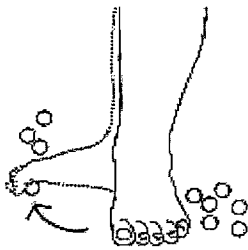


Curl toes over edge of book or plank lying on the ground. Strengthening foot intrinsic muscles helps to support medial foot arch.

Hold exercises for 5 seconds

3 x 10 repetitions, resting 20 seconds between sets.

Toe Marble Pick up (Intrinsic Foot muscles)

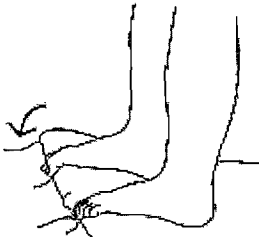


Use toes to pick up loose marbles from a certain area and then drop them in another area.

Hold marble for 5 seconds

Do 3 x 10 repetitions, resting 20 seconds between sets.

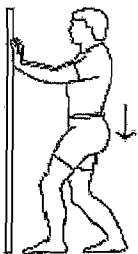
Towel Scrunch (Intrinsic Foot muscles)



Use toes to scrunch up a towel as in the picture.

Do 3 sets of one towel length, resting 20 seconds between sets.

Soleus Stretch (Increases Achilles Tendon Suppleness)

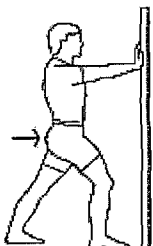


Stand with hands against a wall and then bend the knee, keeping the heel flat on the floor.

Hold each stretch for 30 seconds

Do 3 stretches

Calf Stretch (Increases Achilles Tendon suppleness)



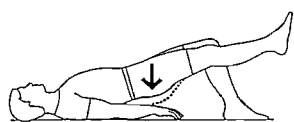
Stand with hands against a wall and lean body forward. Keep rear leg straight and keep heel flat on the floor.

Hold each stretch for 30 seconds

Do 3 stretches

Core Exercises (Stabilising SIJ symmetry):

Bridging with leg extension:



Start exercise by lying on back with legs bent at the knee. Raise the buttocks off the floor and then extend one knee. Hold this position for 30 seconds. Then bend leg again and lower buttocks to the floor slowly. Do 5 repetitions with each leg, resting 20 seconds between sets.

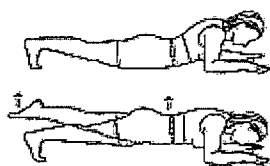
Straight leg raise with abduction:



Press lower back into the floor by tilting pelvis posteriorly. Keep back pressed down against the floor and then lift heels 10cm off the ground. Now slowly open and close legs. Repeat exercise for 30 seconds. Lower legs down to floor again.

Do 3 repetitions, resting 20 seconds between sets.

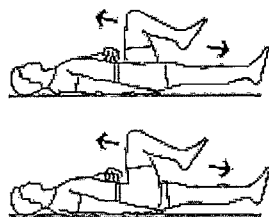
Body bridge with raised leg:



Lie on stomach with elbows supporting upper body. Tighten abdominal muscles and lift stomach off the floor. Now lift up one leg. Hold this position for 30 seconds. Then lower leg and lower body.

Do 2 repetitions with each leg, rest 20 seconds between exercises.

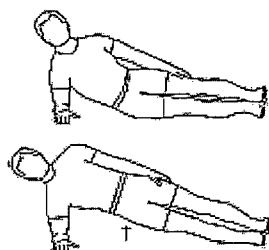
Cycling on back:



Lie on back with legs bent. Press back flat against the floor and bend one leg more while straightening the other. Hold position for 1 second. Now switch legs. Continue switching legs for 45 seconds. Then lower both legs to the floor again and return to the starting position.

Do 3 repetitions of exercise, resting 20 seconds between sets.

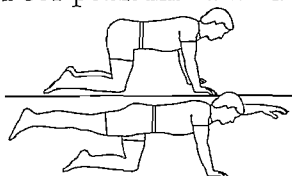
Side bridging:



Start by lying on side with upper body supported on bent elbow. Tighten abdominal muscles and lift hip off the floor, leaving body supported by elbow and feet. Hold this position for 45 seconds. Then slowly lower body down to the floor.

Do 2 repetitions with each side, resting 20 seconds between sets.

Four point kneel with bridging:



Start by kneeling on hands and knees. Then tighten abdominal muscles and lift one arm and one leg in crossed over fashion. Hold this position for 20 seconds. Lower arm and leg slowly and repeat with the other side.

Do 4 repetitions with each side, resting 20 seconds between sets.

Static abdominals:

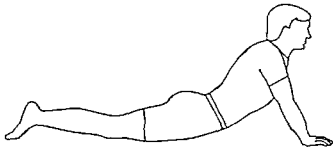


Press hand against raised leg. Press down with the hand, while pressing back with the leg, giving static contraction of abdominals. No movement should occur. Hold position for 30 seconds.

Do 2 repetitions with each side, resting 20 seconds between sets.

Exercises addressing decreased lumbar extension:

Lumbar extension stretch:



Lie on stomach with arms bent underneath upper body. Now straighten arms out and push upper body off the floor, keeping hips on floor. Hold position for 30 seconds.

Do 3 repetitions.

Iliopsoas stretch:



Start in half-kneeling position. Keep upper body upright and lean forward, stretching out the hip flexor muscles. Hold stretch for 30 seconds.

Do 3 repetitions with each side.

Exercises for addressing decreased Straight Leg Raise ROM:

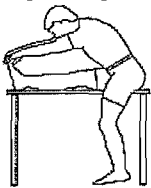
Straight leg raise neural mobilisation:



Bend leg up and support it with hands locked around thigh. Make sure leg can straighten out completely by lowering angle of thigh if needed. Now slowly straighten out knee. Hold position for 2 seconds. Gentle stretching sensation should be felt behind thigh.

Do 20 repetitions with each leg. Rest 20 seconds between sets.

Straight leg raise neural stretch:



Position straight leg on table as in figure. Now lean forward with upper body, reaching as far down leg as possible. Hold position for 30 seconds.

Do 3 repetitions for each side.

Exercises addressing decreased Psoas muscle length:

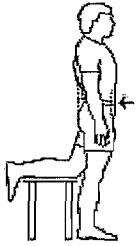
Iliopsoas stretch:



Start in half-kneeling position. Keep upper body upright and lean forward, stretching out the hip flexor muscles. Hold stretch for 30 seconds.

Do 3 repetitions with each side.

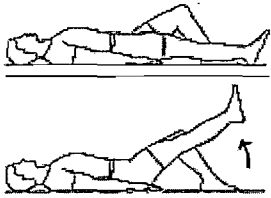
Iliopsoas stretch with bench:



Stand with leg positioned on bench as in figure. Lean forward with body, stretching out leg to the rear. Hold stretch for 30 seconds.
Do 3 repetitions with each side.

Exercises for VMO addressing patella squint:

Straight Leg Raise (VMO):



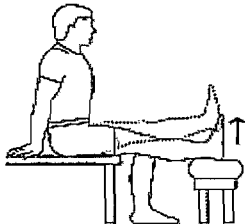
Lie on back with one leg bent and the other straight. Turn the toes of the straight leg slightly outward by rotating leg and slowly lift leg up straight, to a height of 15cm. Keep knee muscle contracted to keep knee extended the whole time. Hold this position for 2 seconds. Slowly lower leg down again. Exercise can also be done using cuff weights for resistance.
Do 3 sets of 20 repetitions with each leg.

Terminal Knee Extension (VMO):



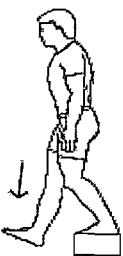
Lie on back with leg bent over a high pillow. Turn the toes slightly outward by rotating leg and straighten leg out, locking knee at the end of extension. Hold this position for 2 seconds, then slowly lower leg down again. Exercise can also be done using cuff weights for resistance.
Do 3 sets of 20 repetitions with each leg.

Seated Straight Leg Raise (VMO):



Sit with leg extended, resting on a bench. Contract the quadriceps muscles to straighten out the knee. Turn toes out slightly by rotating leg and lift leg 15cm off bench. Hold raised position for 2 seconds and slowly lower down. Exercise can also be done using cuff weights for resistance.
Do 3 sets of 20 repetitions.

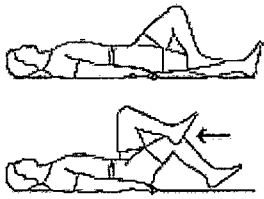
Step Down (Eccentric VMO):



Start by standing on a 20cm step. Now slowly step down with one leg, carefully controlling the movement. Then return to the starting position. Exercise can be done with hand weights for resistance.
Do 3 sets of 20 repetitions.

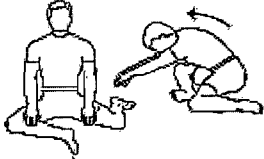
Exercises for addressing decreased Gluteal muscle length:

Gluteal muscle stretch:



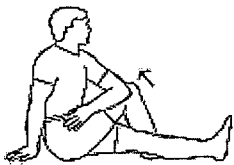
Cross left leg over the right leg, putting left heel next to right knee. Now bend right hip and knee until stretch is felt in buttock area. Hold stretched position for 30 seconds. Now lower down and repeat with other side. Do 3 repetitions with each leg.

Piriformis stretch:



Sit on floor with one leg bent in front of body and the other leg bent behind body, as in figure. Now lean forward until stretch is felt in buttock. Hold this stretched position for 30 seconds. Repeat with other side, by switching legs. Do 3 repetitions with each side.

Gluteal muscle stretch:



Start in seated position. Keep left leg straight and bend right leg over left leg as in figure. Now apply pressure to outside of right leg using elbow and push leg over towards the left. Push until stretch is felt in buttock. Hold this stretched position for 30 seconds. Switch sides and repeat with other leg. Do 3 repetitions with each side.

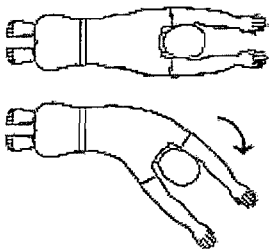
Exercises for addressing lumbo-pelvic dysfunction:

Lumbar rotation:



Start in standing position. Now keep the hips still and rotate the upper body as far as possible to left. Hold this position for 5 seconds. Now rotate to the right and hold for 5 seconds. Do 10 repetitions to each side.

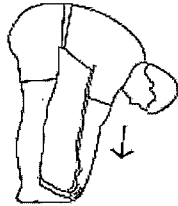
Thoraco-lumbar fascia stretch:



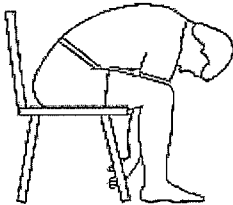
Start by standing on hands and knees. Then straighten arms straight above head. Now bend body over to the right, as in the figure, until stretch is felt in the lower back. Hold this position for 30 seconds and then return to the starting position. Repeat stretch to other side. Do 3 repetitions to each side.

Kneeling Lumbar Flexion stretch:

Start by standing on hands and knees. Then lean backwards, until buttocks are rested on heels. Hold this position for 30 seconds.
Do 3 repetitions.

Standing Lumbar Flexion stretch:

Start in standing position. Now bend upper body downwards, trying to touch toes. Keep legs straight. Hold this position for 30 seconds.
Do 3 repetitions.

Seated Lumbar Flexion stretch:

Start by sitting on chair. Now lean forward, reaching under chair as far as possible with hands. Keep buttocks flat on chair. Hold position for 30 seconds.
Do 3 repetitions.

Side Flexion stretch:

Start by lying on side, supported by elbow. Now straighten out supporting arm, keeping hips flat on the floor. Hold this position for 30 seconds. Now repeat to the opposite side.
Do 3 repetitions to each side.

**Plyometric Exercises:****Single leg vertical power jump:**

Start standing with arms slightly flexed next to sides on one leg, with other leg bent at hip. Bend knee to half squat position and explode into jump extending hip, knee and ankle. Also extend arms above head and try to reach up to maximum height. Land in half squat position on one leg with arms bent next to sides and immediately explode into next jump. Rest 15 seconds between sets.

Single leg hop:



Start standing on one leg with arms next to sides, behind line. Jump over the line and land on same leg. Immediately jump again upon landing. Jump 15m on one leg. Switch legs and jump back to starting position. Rest 15 seconds and repeat. Do 2 lengths with each leg. Attempt for maximal horizontal distance with each jump.

Standing Triple jump:



Start standing with arms slightly flexed next to sides. Perform a long jump and land on left leg. Immediately jump and land on right leg. Then immediately jump and land on both legs. Take a moment and repeat. Do 10 repetitions and rest 30 seconds. Then do 10

repetitions landing on right leg first.

Lateral Bound:



Start standing with both legs together in a semi-squat position and hands hanging down in front, next to line. Jump sideways with both legs over the line and land as far as possible on the other side on the outside leg, with the other leg following afterwards. Upon landing, reset to starting position and jump back to other side. Jump 10 times to each side. Rest 15 seconds and repeat.

Alternate leg bound:



Start standing with arms slightly flexed next to sides. Perform a bound with left leg and land on right leg. Upon landing, immediately bound with right leg and land on left leg. Do 10 repetitions and rest 15 seconds. Then do 10 repetitions landing on left leg first. Try to attain maximum

distance with each bound.

Scissor Jumps:



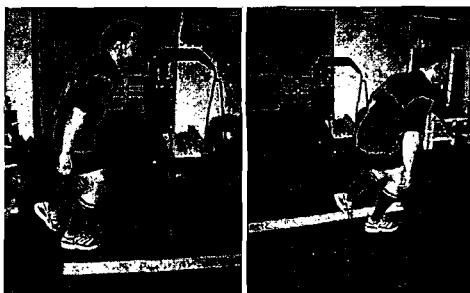
Start standing in lunge position with hands on hips. Jump vertically upwards. Straighten legs while in the middle of the jump. Switch legs at this stage while in the air and land in the starting position, with the back leg now in front. Back knee should not touch ground upon landing. Repeat 10 times. Do 2 sets. Rest 15 seconds between sets.

Single leg lateral hop:



Stand on one leg with arms next to sides, next to line. Jump over the line and land on same leg on other side. Immediately jump back to original side upon landing. Jump 10 times to each side. Rest 15 seconds and repeat with other leg. Do 2 sets with each leg.

Single leg diagonal hop:



Start standing on one leg with arms next to sides, next to line. Jump over the line diagonally and land on same leg on other side. Immediately jump diagonally back to other side again upon landing. Jump 15 m on one leg. Switch legs and jump back to starting position. Rest 15 seconds and repeat. Do 2 lengths with each leg. Attempt for maximal distance with each jump.

Single leg diagonal bound:



Start standing on left leg with arms next to sides, next to line. Jump over the line diagonally and land on right leg on other side of the line. Upon landing immediately jump diagonally back to other side again, landing on left leg. Continue bounding diagonally across line, landing on different foot each time. Jump a distance of 15 m. Rest 15 seconds and repeat. Do 4 lengths.