



# **Anthropometric profile, selected physical parameters, technical skills and match demands of university-level female soccer players**

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# DECLARATION

I, Anita Strauss, hereby declare that this thesis submitted for the degree Doctor of Philosophy in Human Movement Science is my own original work and has not previously been submitted to any other institution of higher education. All materials from published sources contained herein have been duly acknowledged.

This thesis serves as fulfilment of the requirements for the degree Doctor of Philosophy in Human Movement Science within the Research Entity Physical Activity, Sport and Recreation in the Faculty of Health Sciences at the North-West University (Potchefstroom Campus). The co-authors of the three articles, which form part of this thesis, Dr Martinique Sparks (Promotor) and Prof Cindy Pienaar (Co-promotor), hereby give permission to the candidate, Mrs Anita Strauss to include the three articles as part of the PhD thesis. The contribution (advisory and supportive) of the co-authors was kept within reasonable limits, thereby enabling the candidate to submit this thesis for examination purposes.

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Prof Cindy Pienaar

Co-promotor and co-author

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# ABSTRACT

## **Anthropometric profile, selected physical parameters, technical skills and match demands of university-level female soccer players**

Female soccer has increased in popularity in recent years. No research exist on the physical and match performance of female soccer players in South Africa, while limited information discussing these components on sub-elite level across the world is available. Certain morphological characteristics seem to be a distinguishing factor between playing positions. Although morphological characteristics are important for sport performance, physical fitness and technical skills are factors that can distinguish players of different standard. More emphasis is placed on high-intensity training programmes of female players to enhance match performance. Sport coaches and conditioning specialist need an understanding of the physical traits of players and the match demands players face to plan training programmes for enhancing match performance.

Consequently, the main objectives of this study were firstly to examine if there are position-specific differences in the morphological characteristics of South African sub-elite female soccer players. Secondly, to evaluate the effect of aerobic and anaerobic fatigue on the technical skills performance of sub-elite female soccer players. Thirdly, to assess the internal and external match demands of sub-elite female soccer players within and between matches during a tournament.

Selected groups of university-level female soccer players were recruited to complete the physical assessments within a two-week period either before or after a tournament. The global positioning system (GPS) and heart rate (HR) data of the players were recorded during an official soccer tournament.

The first objective of the study was achieved by using a quantitative research method through a descriptive design. The players were purposefully selected and representative of players competing on sub-elite level. Data from 101 female players (age:  $21.8 \pm 2.7$  years, standing height:  $160 \pm 6.8$  cm, body mass:  $57.1 \pm 9.1$  kg) were collected with a demographics questionnaire and anthropometric datasheet. Twenty anthropometric sites were measured to determine body composition and somatotype. Body fat percentage (BF%) was  $20.8 \pm 5.7\%$  and the somatotype indicated a balanced endomorph (4.0–2.4–2.1) body type. Significant ( $p \leq 0.05$ ) differences between goalkeepers and the outfield playing positions were noted in morphological features. The outfield playing positions did not differ significantly ( $p \leq 0.05$ ) from one another.

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Goalkeepers were taller, heavier, possessed the highest BF% and showed higher values for all skinfold, breadth, girth and length measurements. Defenders showed the second-highest breadth and girth measurements. Midfielders were the shortest and lightest players, with the lowest BF% and the lowest values in most measurements. Positional groups did not differ significantly ( $p \leq 0.05$ ) in somatotype characteristics. Morphological differences therefore exist between different playing positions.

In order to fulfil the second objective, a demographic questionnaire and a physical performance and technical skill datasheet were used. Data from 48 South African sub-elite female soccer players (age:  $22.0 \pm 2.7$  years; standing height:  $158.9 \pm 5.8$  cm; body mass:  $55.5 \pm 8.1$  kg) were used for analysis. Players completed the Loughborough Soccer Passing Test before and directly following the execution of an anaerobic repeated sprint ability (RSA) test and an aerobic Yo-Yo Intermittent Recovery Level 1 (Yo-Yo IR1) test on two consecutive days. Penalty time (32.6%) and total performance time (10.1%) increased significantly ( $p < 0.001$ ) following the Yo-Yo IR1. Penalty time (20.4%) and total performance time (8.5%) also increased following the RSA test. Peak heart rate values of 190 bpm and 186 bpm were recorded following the aerobic and anaerobic fitness tests, respectively. Although aerobic fatigue will influence technical skill performance more than anaerobic fatigue, both forms of fatigue would affect performance negatively.

The third objective was achieved through an observational study. Data from 30 sub-elite female soccer players (age:  $22.8 \pm 2.4$  years; standing height:  $158.6 \pm 4.5$  cm; body mass:  $54.1 \pm 6.1$  kg) representing two university teams during a tournament were collected through GPS units sampling at 10 Hz, and equipped with 100 Hz accelerometer. The activity profiles of the starting line-up were recorded during all matches, providing 84 individual match files. Data of players who completed full matches were analysed. Players were categorised according to playing position, namely forwards, midfielders and defenders. Goalkeepers were excluded from the analysis. Each team was monitored for five matches during the course of a week-long tournament. The matches were played on a standardised soccer field and consisted of two 35 minute halves. Comparisons were made based on different GPS-derived variables, including total distance, distances covered in different velocity zones, low-intensity activities (LIA), moderate-intensity activity, high-intensity activities (HIA) and corresponding heart rates, work rate and player load (PL). Differences in match demands within and between matches were assessed using percent difference, effect size and 90% confidence intervals. Midfielders covered the greatest absolute and relative total distances, and achieved the highest LIA and PL per minute of play. Defenders covered significantly ( $p \leq 0.05$ ) less relative distance and LIA per minute of play compared to midfielders. Forwards covered the greatest distance at high-intensity (HI), while the

greatest percentage of time at high-intensity heart rate was measured among the defenders. Within match comparisons showed that player load decreased significantly ( $p \leq 0.05$ ) in the second half (ES: 0.4). Relative distance, LIA and HIA also decreased in the second half with possibly trivial to likely small changes. Small to large differences in variables were observed throughout the tournament. The biggest magnitude of change was seen with a large decrease (ES: -1.2) in relative distance covered between Match 2 and 5. Evidence suggests that accumulated fatigue throughout a multi-day tournament would affect performance negatively.

Keywords: aerobic fitness, anaerobic fitness, fatigue, high-intensity activity, Loughborough Soccer Passing Test, match analysis, morphology, technical skills

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# OPSOMMING

## **Antropometriese profiel, bepaalde fisiese beperkings, tegniese vaardighede en wedstrydeise van universiteitsvlak vroue sokkerspelers**

Vroue sokker het toenemend populêr geword die afgelope paar jaar. Geen navorsing bestaan oor die fisiese en wedstrydprestasie van vroue sokkerspelers in Suid-Afrika nie, alhoewel daar is beperkte inligting wêreldwyd beskikbaar wat hierdie komponente van subelitevlak bespreek. Sekere morfologiese eienskappe blyk om 'n bepalende faktor tussen speler posisies te wees. Alhoewel morfologiese eienskappe belangrik vir sportprestasie is, is fisiese fiksheid en tegniese vaardighede faktore wat spelers van verskillende standarde onderskei. Al meer klem word geplaas op hoë-intensiteit oefenprogramme vir vrouespelers om wedstrydprestasie te bevorder. Sportafrigters en kondisioneringspesialiste het 'n begrip van die fisiese kenmerke van spelers en die wedstrydeise wat spelers in die gesig staar nodig om oefenprogramme te beplan om prestasie te handhaaf.

Gevolgtrek was die hoofdoelwitte vir hierdie studie om eerstens te bepaal of daar posisie-spesifieke verskille in die morfologiese eienskappe van Suid-Afrikaanse subelite vroue sokkerspelers is. Tweedens, om die uitwerking van aërobiese en anaërobiese uitputting op die tegniese vaardighedsprestasie van subelite vroue sokkerspelers te evalueer. Derdens, om die interne en eksterne wedstrydeise van subelitevlak vroue sokkerspelers gedurende 'n toernooi te evalueer.

Gekeurde groepe universiteitsvlak vroue sokkerspelers is genader om die fisiese assesserings binne 'n twee weke lange tydperk te voltooi, voor of na 'n toernooi. Die globale positioneringstelsel (GPS) en harttempo (HT) gegewens van die spelers was opgeneem gedurende 'n amptelike sokkertoernooi.

Die eerste doelwit van die studie is bereik deur 'n kwantitatiewe studie met 'n beskrywende navorsingsontwerp. Die spelers is doelbewus gekeur en is verteenwoordigend van spelers wat op subelite vlak meeding. Data van 101 vrouespelers (ouderdom:  $21.8 \pm 2.7$  jaar, lengte:  $160 \pm 6.8$  cm, liggaamsmassa:  $57.1 \pm 9.1$  kg) is versamel met 'n demografiese vraelys en antropometriese datablad. Twintig antropometriese punte is gemeet om liggaamsamestelling en liggaamstipe te bepaal. Die persentasie liggaamsvet was  $20.8 \pm 5.7\%$  en die liggaamstipe het 'n gebalanseerde endomorfiëse ( $4.0-2.4-2.1$ ) liggaamstipe gedui. Merkwaardige ( $p \leq 0.05$ ) verskille tussen doelwagters en die buiteveldposisies is in die morfologiese gebruiksfunksies opgemerk. Die buiteveldposisies het nie geweldig ( $p \leq 0.05$ ) van mekaar verskil nie.

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Doelwagters is langer, swaarder en het die hoogste persentasie liggaamsvet en het hoër waardes vir alle veldikte, breedte, omtrekke en lengte afmetings getoon. Verdedigers het die tweede hoogste breedte- en omtrekmaatafmetings getoon. Binneveldspelers is die kortste en ligste spelers met die laagste liggaamsvet en die laagste waardes in die meeste afmetings. Posisionele groepe verskil nie merkwaardig ( $p \leq 0.05$ ) in liggaamstipe eienskappe nie. Morfologiese verskille tussen spelers in verskillende spelposisies bestaan dus.

Om sodoende die tweede doelwit te bereik was 'n demografiese vraelys en 'n fisiese prestasie- en tegniese vaardighedsdatablad gebruik. Data van 48 Suid-Afrikaanse subelite vroue sokkerspelers (ouderdom:  $22.0 \pm 2.7$  jare; lengte:  $158.9 \pm 5.8$  cm; liggaamsmassa:  $55.5 \pm 8.1$  kg) is gebruik vir ontleding. Spelers voltooi die Loughborough Sokkerpas Toets voor en direk na die uitvoering van 'n anaërobiese herhaaldelike naelvermoë (HNV) toets en 'n aërobiese Yo-Yo Intermittent Recovery Level 1 (Yo-Yo IR1-bepaalde) toets op twee opeenvolgende dae. Straftyd (32.6%) en totale prestasietyd (10.1%) het merkwaardig toegeneem ( $p < 0.001$ ) na die voltooiing van die Yo-Yo IR1-bepaalde toets. Straftyd (20.4%) en totale prestasietyd (8.5%) het ook toegeneem na die HNV toets. Piek hartklopspoedwaardes van 190 slae per minuut en 186 slae per minuut is opgeneem na die aërobiese en anaërobiese fiksheidstoetse, onderskeidelik. Alhoewel aërobiese uitputting tegniese vaardighedsprestasie meer as anaërobiese uitputting sal beïnvloed, sal beide vorme van uitputting 'n negatiewe uitwerking hê.

Die derde doelwit was bereik deur 'n waarnemingstudie. Data van 48 Suid-Afrikaanse subelite vroue sokkerspelers (ouderdom:  $22.8 \pm 2.4$  years; lengte:  $158.6 \pm 4.5$  cm; liggaamsmassa:  $54.1 \pm 6.1$  kg) verteenwoordigend van twee universiteitspanne gedurende 'n toernooi is ingesamel deur GPS-steekprofeenhede teen 10 Hz en toegerus met 100 Hz versnellingsmeters. Die aktiwiteitsprofiel van die beginspan is opgeneem gedurende al die wedstryde, gegewe 84 individuele wedstrydlêers. Data van spelers wat volledige wedstryde voltooi het, is ontleed. Spelers is gekategoriseer volgens die spelposisie, naamlik voorspelers, binneveldspeler en verdedigers. Doelwagters was uitgesluit van die ontleding. Elke span was vir 5 wedstryde gemonitor gedurende die duur van 'n week lange toernooi. Die wedstryde is op 'n standaard sokkerveld gespeel en het uit twee 35 minute helftes bestaan. Vergelykings is gemaak gebaseer op verskillende GPS verkrygte veranderlikes, insluitende totale afstand, totale afstande in verskillende snelheidsone, lae-intensiteit aktiwiteite (LIA), matige-intensiteit aktiwiteite, en hoë-intensiteit aktiwiteite (HIA) en ooreenkomstige HT, werkkoers en spelerlading (SL). Verskille in wedstrydvereistes gedurende en tussen wedstryde was geassesseer met persentasieverskille, effekgrootte en 90% vertrouensintervalle. Binneveldspelers het die grootste totale en relatiewe afstande afgelê en het die hoogste LIA en SL per minuut van die spel. Verdedigers het merkwaardig ( $p \leq 0.05$ ) minder relatiewe afstande afgelê en LIA per minuut van die spel in

vergelyking met binneveldspelers. Voorspelers dek die grootste afstande teen hoë-intensiteit, terwyl die grootste persentasie van tyd teen hoë-intensiteit harttempo gemeet is onder die verdedigers. Gedurende wedstrydvergelykings dui dat spelerlading merkwaardig ( $p \leq 0.05$ ) afneem in die tweede helfte (EG: 0.4). Relatiewe afstand, LIA en HIA het ook afgeneem in die tweede helfte met moontlik onbeduidende tot klein veranderinge. Klein tot groot verskille in veranderlikes is opgemerk regdeur die toernooi. Die grootste aantal verandering is opgemerk met 'n groot afname (EG: -1.2) in relatiewe afstand afgelê tussen wedstryd 2 en 5. Bewyse dui dat opgeboude uitputting regdeur 'n toernooi oor verskeie dae prestasie negatief sal beïnvloed.

Sleutelwoorde: aërobiese fiksheid, anaërobiese fiksheid, uitputting, hoë-intensiteit aktiwiteit, Loughborough Sokkerpas Toets, wedstrydontleding, morfologie, tegniese vaardighede

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# LIST OF ABBREVIATIONS

<b><u>ABBREVIATION</u></b>	<b><u>MEANING</u></b>
%	Percentage
ANOVA	Analysis of variance
BF%	Body fat percentage
bpm	Beats per minute
CI	Confidence interval
cm	Centimeter
CV	Coefficient of variance
DF	Defenders
ES	Effect size
FI	Fatigue index
FIFA	Fédération Internationale de Football Association
FW	Forwards
HDOP	Horizontal Dilution of Position
GK	Goalkeepers
GPS	Global Positioning System
H <sub>ACC.</sub>	High acceleration
H <sub>DEC.</sub>	High deceleration
HI	High-intensity
HIA	High-intensity activity

HIHR	High-intensity heart rate
HIR	High-intensity running
HR	Heart rate
HR <sub>max</sub>	Maximum heart rate
HR <sub>mean</sub>	Mean heart rate
HR <sub>peak</sub>	Peak heart rate
Hz	Hertz
ISAK	International Society for the Advancement of Kinanthropometry
kg	Kilogram
km	Kilometers
km/h	kilometres per hour
L/min	Litres per minute
L <sub>ACC.</sub>	Low acceleration
L <sub>DEC.</sub>	Low deceleration
LI	Low-intensity
LIA	Low-intensity activity
LIR	Low-intensity running
LIST	Loughborough Intermittent Shuttle Test
LSPT	Loughborough Soccer Passing Test
LSST	Loughborough Soccer Shooting Test
m	Meters
m/min	Meter per minute

m/s	Meter per second
m/s <sup>2</sup>	Meter per second squared
M <sub>ACC.</sub>	Moderate acceleration
M <sub>DEC.</sub>	Moderate deceleration
MF	Midfielders
min	Minutes
ml/kg/min	Millilitres per kilogram per minute
mLSPT	Modified version of the Loughborough Soccer Passing Test
n	Number of subjects
NCAA	National Collegiate Athletic Association
NWU	North-West University
p	Statistical significance
PhASRec	Physical Activity, Sport and Recreation Focus Area
r	Correlation coefficient
RPE	Rating of perceived exertion
RSA	Repeated sprint ability
s	Seconds
SD	Standard deviation
SEE	Standard error of estimate
T <sub>DEC.</sub>	Total deceleration
TEM	Technical Error of Measurement
TMA	Time-motion analysis

US	Unites States
USA	United States of America
VO <sub>2</sub>	Oxygen uptake
VO <sub>2max</sub>	Maximum oxygen uptake
Yo-Yo IE2	Yo-Yo intermittent endurance test level 2
Yo-Yo IR	Yo-Yo intermittent recovery test
Yo-Yo IR1	Yo-Yo intermittent recovery test level 1
Yo-Yo IR2	Yo-Yo intermittent recovery test level 2

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# **CHAPTER 1**

## **INTRODUCTION, PROBLEM STATEMENT AND PURPOSE OF THE STUDY**

## 1.1 Introduction

Soccer is the world's most popular sport, with many females also taking an interest in becoming professional athletes in this sport (Stølen *et al.*, 2005:502; Milanovic *et al.*, 2012:68). Female soccer is regarded as one of the most popular female sports worldwide (Haugen *et al.*, 2012:340). According to the Fédération Internationale de Football Association (FIFA) Women's Football Survey of 2014, around 30 million females across all ages play soccer (FIFA, 2014). A recent report showed that there are 1 270 481 registered Union of European Football Associations (UEFA) female players in Europe (UEFA, 2017). The South African Football Association (SAFA) is the national association of football in South Africa with the SAFA Sasol Women's League being the premier football league for females with over 2800 female players competing on a regular basis (SAFA, 2018). However, despite the high participation rates, more research is required on female soccer (Haugen *et al.*, 2012:340). The increase in the different levels of competition for female players has resulted in a large number of players now have the opportunity to participate professionally (Martínez-Lagunas *et al.*, 2014:258). In order to earn a position in a professional or national team, female players are engaging in high-intensity (HI) training programmes to enable them to compete at their peak fitness levels (Vescovi *et al.*, 2006:221). The improvement of match performance in female soccer, therefore, requires studies on the physical aspects, such as morphological characteristics and fitness requirements, over a wide range of competitive levels, including junior, youth and university levels (Hasegawa & Kuzuhara, 2015:51).

## 1.2 Problem statement

Soccer, classified as an intermittent team sport, is characterised by intermittent bursts of HI exercise while simultaneously requiring the execution of complex, sport-specific technical skills over a prolonged period of time (Baker *et al.*, 2015:5734). A variety of different actions are performed during a soccer match, including walking, running, tackling, jumping, accelerating and turning (Gravina *et al.*, 2011:1345). Consequently, soccer players have to adapt to the multi-factorial physical demands of a match (Gil *et al.*, 2007a:25). The physical match demands placed on elite soccer players have increased over the years, and this has resulted in the player profiles of elite performers becoming an area of interest among researchers in this particular field (Bradley *et al.*, 2009:167; Dillern *et al.*, 2012:43). The fundamental aim of training is to improve competitive performance, making the quantification of training of utmost importance when programming tasks and loads that allow optimum preparation for competition (Barbero Álvarez *et al.*, 2008:2). Body composition in soccer players is one aspect of this formula that has proved to be an important factor in identifying a successful player (Sporis *et al.*, 2007:94), since body composition is

regarded as an important indicator of the physical fitness and health of athletes (Mala *et al.*, 2015:207).

According to Can *et al.* (2004:482), morphological factors are essential for successful performance in sports. Goalkeepers and defenders are often taller and heavier compared to midfielders and forwards (Dillern *et al.*, 2012:45; Milanovic *et al.*, 2012:70). Standing height values ranging between 161.3 cm and 171.9 cm have been recorded for elite female soccer players (Sedano *et al.*, 2009:390; Bendiksen *et al.*, 2013:1432; Mara *et al.*, 2017), while ranges between 159.1 cm and 164.3 cm have been reported for sub-elite female players (Nikolaidis, 2014:43; Hasegawa & Kuzuhara, 2015:52). Similar average heights for elite female soccer players in Brazil, Croatia and Denmark were reported by Nakamura *et al.* (2016), Sporis *et al.* (2007:93) and Krusturup *et al.* (2005:1243) respectively. Milanovic *et al.* (2012:70) and Sporis *et al.* (2011:34) reported the greatest average standing height to be among goalkeepers, followed by defenders, and noted that midfielders and forwards were among the shortest players.

Average body mass values ranging between 56.8 kg and 65.3 kg have also been reported (Mujika *et al.*, 2009:109; Manson *et al.*, 2014:311; Mala *et al.*, 2015:210; Mara *et al.*, 2017) for elite female soccer players, with goalkeepers being heavier than players in other positions (Sporis *et al.*, 2011:34; Dillern *et al.*, 2012:45). The body mass of sub-elite players is reportedly lower (54.7–60.5 kg) than elite players (Nikolaidis, 2014:43; Hasegawa & Kuzuhara, 2015:52). Furthermore, body fat percentage (BF%) values ranging between 15.5% and 24.7% were found among elite and sub-elite female soccer players (Gravina *et al.*, 2011:1346; Hasegawa & Kuzuhara, 2015:52). Evidence suggests that goalkeepers have the highest BF% (Sedano *et al.*, 2009:390; Hasegawa & Kuzuhara, 2015:52). According to Milanovic *et al.* (2012:68), body mass and BF% form part of the physiological makeup of soccer players. Evidence was provided that a high negative correlation exists between BF% and performance in activities such as jumping and sprinting (Can *et al.*, 2004:483). In classifying somatotype characteristics, mesomorphy is usually the most predominant somatotype component in soccer players (Gil *et al.*, 2007b:438). Studies show that female soccer players tend to have an endomorphic mesomorph somatotype (Can *et al.*, 2004:482; Adhikari & Nugent, 2014:15).

Although a series of studies was conducted regarding the anthropometric characteristics of soccer players, studies on the physical capacities further provide a better understanding of the important factors behind soccer performance (Kulkarni *et al.*, 2013; Nikolaidis, 2014; Popović *et al.*, 2014; Hasegawa & Kuzuhara, 2015; Nakamura *et al.*, 2016). According to Bangsbo *et al.* (2008:38), the aerobic and anaerobic capacity of an athlete may determine the outcome of a competition. Previous studies making use of physiological data (internal match demands) such as heart rate

(HR) recordings and metabolic measurements of muscle and blood samples collected during competition have reported that in many sports, the aerobic loading and anaerobic energy turnover is high throughout periods of competition (Bangsbo, 1993; McInnes *et al.*, 1995; Krstrup *et al.*, 2006). Bangsbo *et al.* (2008:38) acknowledged that it is, therefore, imperative to evaluate the players' abilities within these areas. Female soccer players have a maximum oxygen uptake  $\dot{V}O_{2max}$  value ranging between 43.4 ml/kg/min and 56.6 ml/kg/min (Krstrup *et al.*, 2005:1245; Haugen *et al.*, 2014:517). Continuous exercise tests used to assess the aerobic capacity of an athlete include a multistage 20 metre shuttle run test, a 12-minute running test, and a  $\dot{V}O_{2max}$  test (Leger & Lambert, 1982:2; Bangsbo *et al.*, 2008:38). The relevance of these tests to intermittent sports has, however, been questioned (O'Reilly & Wong, 2012:1033; Deprez *et al.*, 2014:903). Thus, the Yo-Yo intermittent recovery (Yo-Yo IR) tests were developed (Bangsbo, 1993). Due to specificity and practicality, the Yo-Yo IR tests have been used in many team sports to assess the players' abilities to perform HI exercise repeatedly (Bangsbo *et al.*, 2008:38; Krstrup *et al.*, 2010:438; Hasegawa & Kuzuhara, 2015:53). The Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) is a good predictor of an elite female soccer player's ability to perform HI running throughout competitive matches and can be used as an indicator of physical match performance (Krstrup *et al.*, 2005:1248). Elite female soccer players typically achieve Yo-Yo IR1 distances of 889.5–1379.0 m (Krstrup *et al.*, 2005:1245; Milanovic *et al.*, 2012:70; Hasegawa & Kuzuhara, 2015:53), with goalkeepers achieving the lowest scores (Hasegawa & Kuzuhara, 2015:53).

Various studies have used time-motion analysis (TMA) to determine the movement and physical demands of soccer (Andersson *et al.*, 2010; Bradley *et al.*, 2013; Bush *et al.*, 2015; Dalen *et al.*, 2016). Although commonly used, TMA methods have limitations with regard to categorisation of locomotor activities, subjectivity involvement when interpreting the data (Cunniffe *et al.*, 2009:1195) and measurement error (Duthie *et al.*, 2003:983). Recent developments in global positioning systems (GPS) technology have provided the means to overcome the logistical problems and limitations of TMA methods that quantify athlete locomotion (Portas *et al.*, 2010:448). It was also established by Varley *et al.* (2012:125) that the 10 Hz GPS devices are two to three times more accurate in detecting velocity changes and up to six times more reliable than the 5 Hz GPS devices. The use of GPS technology simultaneously captured with HR monitoring is now routinely used in team sports to assess the physiological and movement demands of athletes (Barbero Álvarez *et al.*, 2008; Cunniffe *et al.*, 2009; Inglis & Bird, 2017; Ramos *et al.*, 2017; Trewin *et al.*, 2018). Other methods that are used together with HR monitoring for the assessment of internal match demands include the assessment of blood lactate concentration (Baumgart *et al.*, 2014:228) and the rating of perceived exertion (RPE) (Sjokvist *et al.*, 2011:1728).

A study conducted by Hewitt *et al.* (2014:1876) using GPS technology found that elite female soccer players covered a mean total distance of 9.6 km during a match. A total of 2 407 m was covered at high-intensity running (HIR) and 338 m while sprinting (Hewitt *et al.*, 2014:1876). Hewitt *et al.* (2014:1876) also noted that midfielders covered the greatest average distance, followed by forwards and defenders. The development of GPS technology purposely designed for team sports such as soccer could supply the necessary tools to gain a greater understanding of the female players' activity profiles of these intermittent, HI activities (Barbero Álvarez *et al.*, 2008:3). According to Reilly *et al.* (2000:670), competitive match play requires an all-out sprint once every 90 s on average and HI efforts every 30 s. Sprinting and HIR constitutes 8–12% of the total distance covered during a match (Krustrup *et al.*, 2005:1244; Gabbett & Mulvey, 2008:548; Mohr *et al.*, 2008:345; Bradley *et al.*, 2009:162; Andersson *et al.*, 2010:915). The ability to perform repeated sprints with minimal recovery between sprint bouts, termed repeated sprint ability (RSA), is thus an important capacity for team sports athletes (Barbero-Álvarez *et al.*, 2010:232). The total amount of HIR distance covered during a match has further been identified as an important indicator of match performance (Mohr *et al.*, 2003:527). The length of HIR during a soccer match in elite female players has been reported to vary between 0.7 km and 1.7 km (Krustrup *et al.*, 2005:1242).

A study of the match activities of elite (top-level and high-level) female soccer players using TMA reported a change in activity every four seconds, accounting for more than 1 300 activity changes throughout the match (Mohr *et al.*, 2008:345). The players spent 19.4% of the total time during the match standing, 42.8% walking and 27.7% performing low-intensity running (LIR) (Mohr *et al.*, 2008:345). The times spent at HIR and sprinting varied among the top-class and high-level players, with values of 6.0% vs 4.4% and 1.2% vs 0.9% respectively (Mohr *et al.*, 2008:345). According to Krustrup *et al.* (2005:1246), the amount of HIR by female players during a match is related to the training status of the players. In addition, the frequency of HI bouts is influenced by fatigue and is believed to vary among playing positions (Bradley *et al.*, 2009:167; Andersson *et al.*, 2010:919). Match analysis is, therefore, regarded as important in providing essential information to design specific conditioning programmes and thus adjust physical preparation to the precise requirements of each position (Barbero Álvarez *et al.*, 2008:9).

Elite soccer is regarded as a complex sport in which performance is dependent upon numerous factors such as physical fitness, technical skills and team tactics (Rampinini *et al.*, 2009:231; O'Reilly & Wong, 2012:1030). A scarcity exists in published literature regarding the influence of exercise on technical skill performance, which is attributed to a shortage of exercise simulations that replicate the movement demands and technical skills of soccer (Russell & Kingsley,

2011:524). The variability inherent in a match makes it difficult to translate findings from one match to the next (Stone & Oliver, 2009:164). Therefore, the Loughborough Soccer Passing Test (LSPT) was developed, and validity and reliability was established for use in the assessment of the multi-faceted aspects of soccer skills (Ali *et al.*, 2007:1470). This particular test is effective in assessing technical tasks such as dribbling, controlling and passing of the soccer ball (O'Reilly & Wong, 2012:1036). According to Ali *et al.* (2007:1470), players who are more technically skilled will be able to perform the LSPT quicker without compromising their ability to pass accurately and control the ball. The characteristics of soccer together with the required functional activities place great demands on the technical skills of players (Twizere, 2004:1). Players with a higher level of aerobic fitness recover quicker following acute bouts of maximal effort, tend to cover greater distances during a match, carry out more sprints during a match and are able to maintain their technical skills and mental concentration more efficiently towards the latter part of a match (Aziz *et al.*, 2007:10). Players who are fatigued are prone to errors in terms of technical skill performance (Njororai, 2014:62). A study by Rampinini *et al.* (2008:937) found that skill technique, kicking accuracy and dribbling activities measured through the LSPT tend to deteriorate following fatiguing exercise. The decrease in technical skill performance during a match has been attributed to the development of fatigue (Rampinini *et al.*, 2009:232).

Most of the available research relating to the physical profile and match demands of soccer players has been conducted on senior male players (Dey *et al.*, 2010; Randers *et al.*, 2010; Jones *et al.*, 2013; Molinos Domene, 2013; Dalen *et al.*, 2016). However, Sporis *et al.* (2007:92) pointed out that female players are not as well understood or studied as male players. The primary aim of this study was to examine the morphological, fitness and technical skill characteristics of sub-elite female soccer players and assess the match demands placed on players throughout a soccer tournament. The secondary aim was to determine positional differences within these variables assessed. This research could lead to a broadening of specialist sport science knowledge with regard to female soccer and could be significant to others who are interested in exploring the technical skills, the aerobic and anaerobic fitness characteristics and the match activities and demands of sub-elite female soccer players. In particular, the results derived from this study could be used for future comparisons on this level. The use of GPS technology and other methods explained in this study could augment the scarce information dealing with sub-elite female soccer players. In order to design improved training programmes, understanding the physical qualities that best correlate with soccer-related performance could be advantageous. With special reference to the requirements for different playing positions in the team, this research could also enable coaches and sport scientists to compile specific and efficient conditioning programmes in order to prepare players for the demands of the match more effectively. Consequently, this would

result in an improvement in performance and the alignment of the teams' performance with international standards. To the researcher's knowledge, no information exists for sub-elite female soccer players in South Africa that describes both physical and performance characteristics. A clarification on these characteristics and comparison with players from other countries competing on a similar level can enhance knowledge of South African sub-elite players and further encourage similar studies on the national team players, with the aim of enhancing performance and contend against other national level teams.

In view of the literature background, the following research questions were proposed:

- **Research question 1:** Are there position-specific differences in the morphological characteristics of South African sub-elite female soccer players?
- **Research question 2:** What is the effect of aerobic and anaerobic fatigue on the technical skill performance of sub-elite female soccer players?
- **Research question 3:** What are the internal and external match demands of sub-elite female soccer players during a tournament?

### 1.3 Objectives

The objectives of this study were:

- **Objective 1:** To examine if there are position-specific differences in the morphological characteristics of South African sub-elite female soccer players.
- **Objective 2:** To evaluate the effect of aerobic and anaerobic fatigue on the technical skill performance of sub-elite female soccer players.
- **Objective 3:** To assess the internal and external match demands of sub-elite female soccer players within and between matches during a tournament.

### 1.4 Hypotheses

This study was based on the following hypotheses:

- **Hypothesis 1:** There will be significant ( $p \leq 0.05$ ) position-specific differences in the morphological profile of South African sub-elite female soccer players.

- **Hypothesis 2:** Aerobic and anaerobic fatigue will have a significant ( $p \leq 0.05$ ) negative effect on the technical skill performance of sub-elite female soccer players.
- **Hypothesis 3:** The internal and external match demands of sub-elite female soccer players will differ significantly ( $p \leq 0.05$ ) within and between matches in a tournament.

Figure 1 provides a conceptualised framework of the larger project entitled: “Investigating performance indicators and injury risk factors for the development and performance of female soccer players”. An indication of areas where the current study forms part of the larger project is provided by using an “\*”.

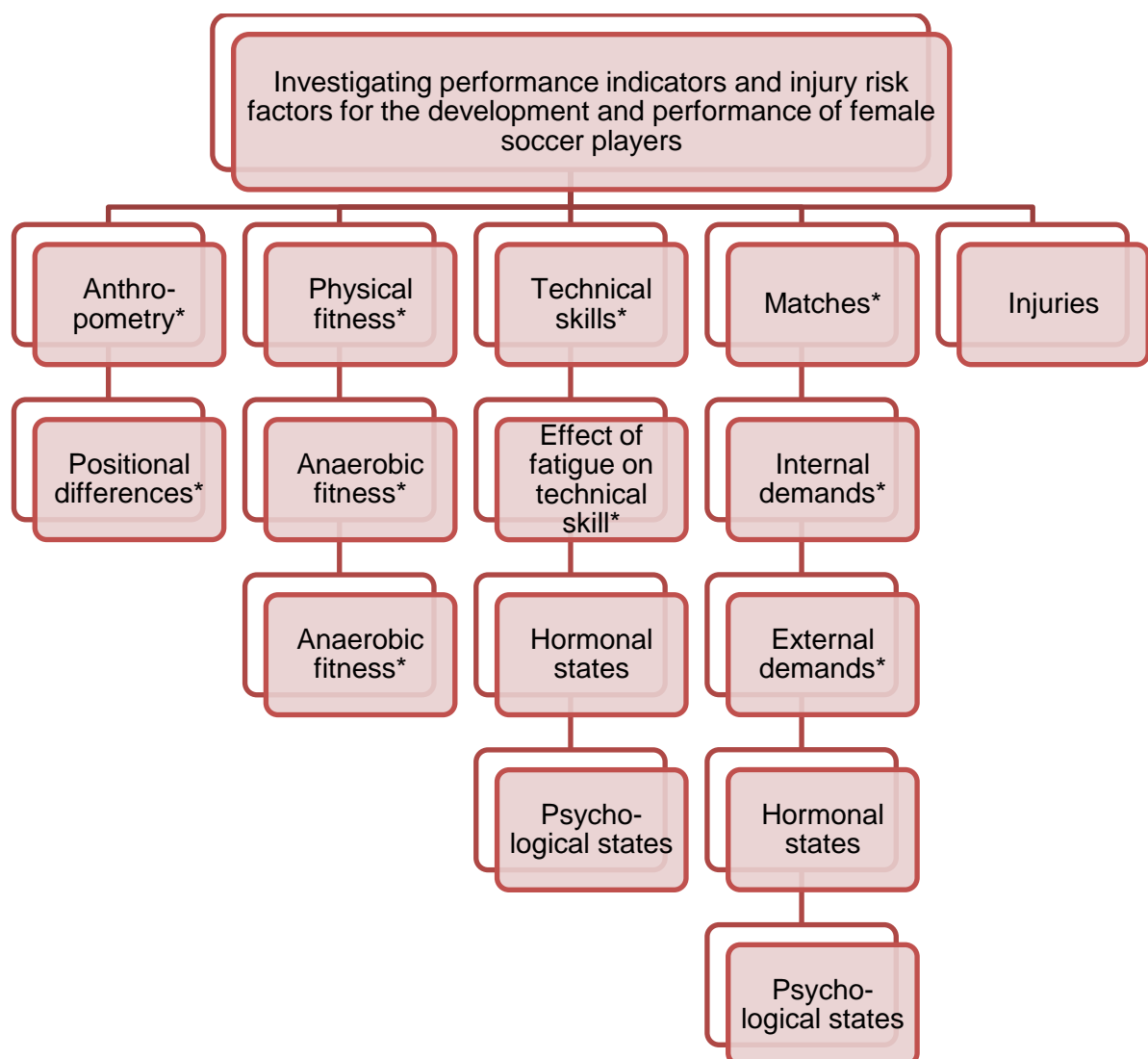


Figure 1: Conceptualised framework of the larger project and interlinking sub-sections of different studies involved. \* Indicates facets investigated in present study

## 1.5 Structure of the thesis

The thesis is to be submitted in article format as approved by the Senate of the North-West University and is structured as follows:

- Chapter 1 Introduction, Problem statement and Purpose of the study. A reference list is provided at the end of the chapter in accordance with the guidelines of the North-West University.
- Chapter 2 Literature overview: Match play analysis, anthropometric measurements and physical profiles of female soccer players. A reference list is provided at the end of the chapter in accordance with the guidelines of the North-West University.
- Chapter 3 Article 1: "Comparison of the morphological characteristics of sub-elite female soccer players according to playing position". This article is submitted to the *Women in Sport and Physical Activity Journal*. The article and the reference list at the end of the article are compiled in accordance with the guidelines of the journal.
- Chapter 4 Article 2: "The effect of exercise-induced fatigue on the technical skill performance of sub-elite female soccer players". This article is submitted to the *Journal of Sports Science and Medicine*. The article and the reference list at the end of the article are compiled in accordance with the guidelines of the journal. Although not according to the guidelines of the journal, tables and figures are included within the text so as to make the article easier to read and understand.
- Chapter 5 Article 3: "The use of GPS analysis to quantify the internal and external match demands of sub-elite female soccer players during a tournament". This article is to be submitted to the *Journal of Strength and Conditioning Research*. The article and the reference list at the end of the article are compiled in accordance with the guidelines of the journal. Although not according to the guidelines of the journal, tables and figures will be included within the text so as to make the article easier to read and understand.
- Chapter 6 Summary, conclusions, limitations and recommendations
- Annexure A: Certificate of Ethics Approval
- Annexure B: Informed consent form

Annexure C: Demographic and general information questionnaire

Annexure D: Forms for the collection of data regarding anthropometric, physical fitness and technical skills

Annexure E: Instructions for authors from the *Women in Sport and Physical Activity Journal*, the *Journal of Sports Science and Medicine*, and the *Journal of Strength and Conditioning Research*.

Annexure F: Authorization letter for reproduction of Loughborough Soccer Passing Test figure

Annexure G: Proof of language editing

Annexure H: Description of testing procedures

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## **CHAPTER 2**

# **LITERATURE OVERVIEW: MATCH PLAY ANALYSIS, ANTHROPOMETRIC MEASUREMENTS AND PHYSICAL PROFILES OF FEMALE SOCCER PLAYERS**

## 2.1 Introduction

Soccer is currently recognised as the most popular sport discipline in the world, with men, women and children competing on different levels (Reilly *et al.*, 2000:669; Stølen *et al.*, 2005:503; Grygorowicz *et al.*, 2013:1). Competitive female soccer has existed since the second half of the 1960s and is played in countries such as Sweden, Denmark, the United States of America (USA), Canada, West Germany, Czechoslovakia, Italy and New Zealand (Hjelm, 2011:156). The mass media started to portray female soccer positively between 1968 and 1971, supporting females who were encroaching on areas previously dominated by men (Hjelm & Olofsson, 2003:187). During the last two decades, female's involvement in soccer has increased considerably, and soccer has become one of the most popular female sports worldwide (La Torre *et al.*, 2008:80; Haugen *et al.*, 2012:340). Female soccer participation has grown in the past years and now boasts over 30 million players worldwide (FIFA, 2015). A total of 24 teams participated in the 2015 FIFA Women's World Cup held in Canada, double the number that participated at the first FIFA Women's World Cup in 1991 (FIFA, 2015). For 2015-2018, FIFA has doubled its funding for female football-specific programmes (FIFA, 2015). In 2015 alone, FIFA is implementing more than 400 activities worldwide in at least 120 countries (FIFA, 2015).

China hosted the first Women's World Cup in 1991, and in 1996, women's soccer became an Olympic discipline at the Summer Olympic Games in Atlanta (Pfister, 2003:135). International competitions and professional and recreational leagues have seen a considerable increase in the number of female players in recent years (Martínez-Lagunas *et al.*, 2014:258). This has given numerous female players the opportunity to train and compete in professional environments, which has simultaneously resulted in an increase in the performance expectations placed upon the players and an increase in the consequent need for specific scientific research that can assist in improving the players' performance (Martínez-Lagunas *et al.*, 2014:259). Despite the increased popularity and professionalisation of female soccer worldwide, scientific research is limited with regard to female players' physical and physiological characteristics and the demands placed on them during matches (Martínez-Lagunas *et al.*, 2014:259). Furthermore, there is an absence of scientific information available regarding the physiological profiles and performance qualities of elite and sub-elite African and South African female players. The identification of the physiological and performance requirements of female soccer players may provide a more objective basis on which coaches can evaluate prospective talent, formulate training programmes and plan team strategies (Can *et al.*, 2004:480). Due to the dearth of related studies, normative data for female players should be established rather than merely implementing extensions of the training programmes currently developed for male players (Sedano *et al.*, 2009:388).

In view of the above-mentioned background, the aim of this literature review is to discuss the current literature pertaining to the anthropometric profiles, the aerobic and anaerobic fitness components and the technical skill characteristics of female soccer players. Furthermore, the author describes both the internal and external match demands placed on female soccer players and investigates the role that fatigue plays during the execution of technical skills and during match play. Even though the main focus of this literature review is on female soccer, due to the scarcity of research articles on female soccer players, articles pertaining to their male counterparts were also considered. Most of the English literature reviewed was confined to the last decade (2008–2018), although older sources were also considered and included due to the scarcity of research available on female soccer. Literature relating to players older than 18 years who competed on club, national and international levels was included.

The review comprises four main sections. The subsequent section focuses on identifying the morphological characteristics of female soccer players and describing positional profiles. Thereafter, the performance variables of female soccer players are discussed, and this is followed by technical skill characteristics. The final section describes the external and internal match demands that are placed on female soccer players.

## **2.2 Morphological profile of female soccer players**

In order to compete at an elite level, soccer players are expected to possess the morphological and physiological characteristics that are applicable both to the specific sporting code and their playing positions (Hazir, 2010:83). Anthropometry provides information regarding major body components such as fat, muscle and bone and makes use of non-invasive, affordable and portable devices to determine skinfolds, body mass, height and body circumferences and diameters (Garrido-Chamorro *et al.*, 2012:803). Recent advances in sport physiology have led to an interest in the development of physiological profiles to describe the qualities and characteristics of athletes in their respective sports (Can *et al.*, 2004:480). Body composition is an essential indicator of the physical fitness and health of athletes and is an important factor in determining the success of soccer players (Rienzi *et al.*, 2000). Mala *et al.* (2015:208) further claim that studies of body composition often focus on relative fatness due to the possible negative influence that excessive fat can have on performance. Morphological characteristics are also important features in the selection process for team positions, especially with regard to goalkeepers (Sporis *et al.*, 2007:94).

Can *et al.* (2004:480) further claim that the morphological characteristics of female soccer players and their performance levels have not been clearly defined in literature. It is, however, challenging

to formulate accurate conclusions on the physical characteristics of soccer players according to playing level and position due to the inconsistency between studies in terms of playing level and playing position (Hazir, 2010:84).

### 2.2.1 Stature and body mass

Standing height is considered a crucial factor for soccer players (Sporis *et al.*, 2007:94). Average standing height values in the range of 161–172 cm have been reported for elite female soccer players in recent studies (Mujika *et al.*, 2009:109; Sedano *et al.*, 2009:390; Krusturp *et al.*, 2010:438; Vescovi, 2012b:475; Bendiksen *et al.*, 2013:1432; Nikolaidis, 2014:43; Mala *et al.*, 2015:210; Mara *et al.*, 2017). For female players participating at sub-elite level, comparable average standing height values have been reported by Vescovi and McGuigan (2008:98), Colak (2012:16) and Adhikari and Nugent (2014:15). Table 1 below indicates the results of these and other studies conducted on female soccer players. A clear distinction between elite and non-elite athletes is not defined in literature. For the purpose of this review, elite players are regarded as players competing on national level and higher divisions, while sub-elite level generally refer to players competing on club, college or university level.

According to Reilly *et al.* (2000:671), there are certain anthropometric predispositions for positional roles, with taller players being more suitable for central defensive positions. A greater standing height in a defender could be favourable in actions in which the ball is received or fought for by the head, both when jumping or standing on the ground (Matković *et al.*, 2003:171). Sporis *et al.* (2007:94) explained that increased standing height is favourable for goalkeepers when defending a goal and found elite female Croatian goalkeepers to be the tallest (174 cm) players in the team. Greater height in goalkeepers is advantageous for match activities that require jumping and reaching for the ball when defending the goal area (Hazir, 2010:91). Standing height values were also reported for forwards (165 cm), midfielders (164 cm) and defenders (166 cm); however, no differences ( $p=0.47$ ) were observed among the playing positions (Sporis *et al.*, 2007:93). Reports by Vescovi *et al.* (2006:223) for sub-elite female players also indicated that goalkeepers were the tallest players (170 cm), followed by defenders (170 cm) and forwards (168 cm).

Similar to the reports of Sporis *et al.* (2007:93), Vescovi *et al.* (2006:223) noted that the shortest players were the midfielders (166 cm). Milanovic *et al.* (2012:70) also found goalkeepers (173 cm) and defenders (170 cm) to be among the tallest players in a group of elite female players, but in contrast to the two sources quoted above, this particular study found forwards (165 cm) to be shorter than midfielders (169 cm). Krusturp *et al.* (2005:1243) did not report on the standing height

values for the elite Danish goalkeepers in their study, although their findings were similar in that defenders (168 cm) were taller than forwards (166 cm) and midfielders (165 cm).

**Table 1: Physical characteristics of female soccer players**

Author	Country & competition level	n	Age (years)	Height (cm)	Body mass (kg)	Body fat (%)
Mara <i>et al.</i> (2017)	Australian elite senior players	12	24.3±4.2	171.9±5.1	65.3±5.1	
Nakamura <i>et al.</i> (2016)	Brazilian elite level	11	21.0±3.0	163.8±4.5	59.7±8.0	
Hasegawa and Kuzuhara (2015:52)	Japanese Aichi College 1 <sup>st</sup> Division	21	19.4±0.9	159.1±4.7	54.7±5.1	24.7±3.1
Mala <i>et al.</i> (2015:210)	Czech Republic National level	18	23.2±4.2	167.3±6.8	61.3±5.5	
Manson <i>et al.</i> (2014:311)	New Zealand international senior players	15	23.3±4.9	168±7.8	64.1±5.4	
Nikolaidis (2014:43)	Greek Amateur club level	54	21.7±4	164.3±4.7	60.5±7	23±4.1
Shalfawi <i>et al.</i> (2014:19)	Norwegian 2 <sup>nd</sup> highest division	30	19.0±4	167±4	57.5±6.9	
Bendiksen <i>et al.</i> (2013:1432)	Norwegian 1 <sup>st</sup> Division	11	21.0±4.5	169.3±5.5	58.7±6	20.6±2.7
Castagna and Castellini (2013:1157)	Italian National Team	21	25.8±3.9	167.3±3.8	59.9±3.8	
Shalfawi <i>et al.</i> (2013:31)	Upper Norwegian league	17	21.2±2.6	168.8±4.6	64±5.9	
Colak (2012:16)	Turkish sub-elite	15	22.1±2.7	164.5±7.6	57.8±7.9	
Haugen <i>et al.</i> (2012:341) (10-year study)	Norwegian National Team	85	23.5±3.6		63.7±5.2	
	Norwegian 1 <sup>st</sup> Division	46	21.2±3.6		62.4±6.6	
	Total group	44	21.9±3.8 (FW)		64.1±6.7 (FW)	
		55	21.6±4.3 (MF)		61.5±4.6 (MF)	
		50	21.6±4.1 (DF)		61.9±5.7 (DF)	
		16	21.4±4.7 (GK)		67.3±4.6 (GK)	
Milanovic <i>et al.</i> (2012:70)	Serbian A-National Team	22	23.9±4.5	168.8±7.2	61.4±6	25.9
				164.7±5 (FW)	62.7±7.7 (MF)	
				168.7±8.7 (MF)	59.5±10.6 (GK)	
				170±7.2 (DF)		
				172.5±3.5 (GK)		

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Author	Country & competition level	n	Age (years)	Height (cm)	Body mass (kg)	Body fat (%)
Vescovi (2012b:475)	USA high level	140	23.9±2.8	167.6±6.1	62.5±6.7	
Gravina <i>et al.</i> (2011:1346)	Spanish 1 <sup>st</sup> Division	14	25.5±5		61±7.4	15.5±2.9
	Spanish 2 <sup>nd</sup> Division	14	8.3±1.5	1	61.9±9.8	18.4±3.3
Ingebrigtsen <i>et al.</i> (2011:3353)	Norwegian 1 <sup>st</sup> and 2 <sup>nd</sup> divisions	29	20.8±3.7	166±5	60.7±6.6	
Sjokvist <i>et al.</i> (2011:1729)	US NCAA 1 <sup>st</sup> Division	14	20.3±2.3	168.1±4.7	61.9±6.5	20.9±3.4
Sporis <i>et al.</i> (2011:34)	Croatian elite level total group	24	18.3±0.6	165.6±4.2	58.3±4.6	21.3±1.5
		4	17.4±0.4 (FW)	165±4.2 (FW)	63.6±4.1 (FW)	20.3±1.7 (FW)
		12	18.3±0.7 (MF)	164±4.3 (MF)	56±4.8 (MF)	21.6±1.8 (MF)
		5	18.5±0.6 (DF)	165.8±3.9 (DF)	56.3±4.9 (DF)	21.8±0.9 (DF)
		3	19.1±0.5 (GK)	172.5±4.6 (GK)	64.4±4.2 (GK)	20.7±1.2 (GK)
Andersson <i>et al.</i> (2010a:601)	Scandinavian highest division	16	22.0±3	167±5	64±2	
Andersson <i>et al.</i> (2010b:913)	Sweden and Denmark national team players	17	27.0±1	168.2±1.5	61±1.4	
Benvenuti <i>et al.</i> (2010:416)	Not specified	18	20.9±3.1	162±7.5	55.2±5.5	
Krustrup <i>et al.</i> (2010:438)	Danish highest division	23	23.0	169	60.1	18.5
Mujika <i>et al.</i> (2009:109)	Spanish 1 <sup>st</sup> Division	17	23.1±2.9	165±0.04	56.8±5.7	
Nesser and Lee (2009:24)	USA NCAA 1 <sup>st</sup> Division	16		163.6±5.2	60.7±7.5	
Sedano <i>et al.</i> (2009:390)	Spanish National Women's 1 <sup>st</sup> Division	100	22.1±1.1	161.3±0.1	57.7±7.5	20.1±5.5
		90	19.1±0.7	161.8±7.1	61.2±10.8	24.6±4.1
	Total group	190		158.1±6.8 (FW)	55.8±7.2 (FW)	21.3±2.7 (FW)
				161.6±4.1 (WM)	58.2±5.4 (WM)	20.9±3.1 (WM)
				162.5±5.7 (MF)	56.5±5.7 (MF)	20.2±2.5 (MF)
				165.7±6.1 (CB)	62.3±7.9 (CB)	25.3±6.3 (CB)
				158.8±6.3 (FB)	56.1±8.8 (FB)	18.1±2.2 (FB)
		160.5±3.1 (GK)	60.1±5.8 (GK)	26.5±3.2 (GK)		

Chapter 2: Literature overview: Match play analysis, anthropometric measurements and physical profiles of female soccer players

Author	Country & competition level	n	Age (years)	Height (cm)	Body mass (kg)	Body fat (%)
Ali <i>et al.</i> (2008:918)	New Zealand Premier Division	19	20.9±4.9	166±5	60.8±6.5	
	New Zealand 1 <sup>st</sup> Division	16	23.3±8.3	166±5	61.9±6.5	
Hewitt <i>et al.</i> (2008:225)	Australian National Team players	15	23.5±2.5	170±5	64.9±4.6	
Vescovi and McGuigan (2008:98)	USA Sub-elite 1 <sup>st</sup> Division	51	19.9±0.9	168±0.06	64.8±5.9	
Gerbino <i>et al.</i> (2007:503)	USA Sub-elite level	32	19.7±1.7	165±5.8	61.2±5.8	
La Torre <i>et al.</i> (2008:81)	Italian Non-professional	13	22.0±3.7	166±6	59.5±5.5	
Smith <i>et al.</i> (2007:471)	USA Sub-elite level 1 <sup>st</sup> Division	19		166.7±5.4	63.3±7.4	
	USA Sub-elite level 3 <sup>rd</sup> Division	15		162.6±5.9	62.9±10.5	
Vescovi <i>et al.</i> (2006:223)	USA Sub-elite 1 <sup>st</sup> Division	64	19.8±1.2	168.4±5.9 168.3±6.6 (FW) 165.9±6.3 (MF) 169.9±4.3 (DF) 170.3±5.7 (GK)	64.8±5.9 64.5±5.8 (FW) 61.3±4.7 (MF) 67±6.7 (DF) 66.4±1.9 (GK)	
Krustrup <i>et al.</i> (2005:1243)	Danish highest division	14	24	167 166.0±4 (FW) 165.0±4 (MF) 168.0±7 (DF)	58.5 58.7±3.8 (FW) 56.0±5.9 (MF) 60.7±6.3 (DF)	14.6 16.1±2.4 (FW) 12.5±2.2 (MF) 15.4±3.7 (DF)
Can <i>et al.</i> (2004:481)	Turkish highest division	17	20.7±2.1	162±0.1	56.6±5.0	19.8±0.7
Todd <i>et al.</i> (2002:376)	English international	25	22.3±4.3	162.8±5.9	61.2±5.2	22.9±3.4
	English Premier League	44	23.4±5.9	163.3±5.5	62.1±6.4	23.9±4.2
	English Regional League	51	21.3±6.6	163.9±6.3	61.6±7.1	25.5±3.5
	Total group	120		162.5±6.8 (FW) 161.6±5 (MF) 165.2±5.6 (DF) 168.5±4.3 (GK)	60.9±7.3 (FW) 59.5±5 (MF) 62.7±6.6 (DF) 68.9±5.5 (GK)	24.3±4.1 (FW) 24.0±3.5 (MF) 24.2±3.9 (DF) 26.3±4.3 (GK)

Source: Adapted from Datson *et al.* (2014:1230). Data are expressed as mean ± standard deviation. Abbreviations: FW: Forwards; MF: Midfielders;

WM: Wide Midfielders; DF: Defenders; CB: Centre-Back; FB: Full-Back; GK: Goalkeepers

In addition to standing height, body mass also forms part of the physical makeup of soccer players (Milanovic *et al.*, 2012:68). Table 1 indicates a reported average body mass range of 56–67 kg for elite female soccer players (Dillern *et al.*, 2012:45; Haugen *et al.*, 2012:341; Bendiksen *et al.*, 2013:1432; Mala *et al.*, 2015:210; Nakamura *et al.*, 2016). When considering playing positions, Sporis *et al.* (2011:34) noted that the goalkeepers (64.4 kg) were the heaviest players in the team, followed by the forwards (63.6 kg), the defenders (56.3 kg) and the midfielders (56.0 kg). It was also noted by Dillern *et al.* (2012:45) that goalkeepers had the highest body mass value (65.6 kg), which was slightly higher than reported by Sporis *et al.* (2007:93). In addition, Dillern *et al.* (2012:45) reported the second-highest values in defenders (61.5 kg), followed by forwards (58 kg) and midfielders (56.6 kg). Differences were, however, reported by Haugen *et al.* (2012:341) following a 10-year study on elite female players, with goalkeepers (67.3 kg) being heavier than midfielders (61.5 kg;  $p=0.008$ ) and defenders (61.9 kg;  $p=0.013$ ). The forward players (64.1 kg) were also found to weigh more than the midfielders and defenders (Haugen *et al.*, 2012:341).

In addition to these reports, a range of 54.7–67 kg was reported for sub-elite level female soccer players (Vescovi *et al.*, 2006:223; Benvenuti *et al.*, 2010:416; Hasegawa & Kuzuhara, 2015:52). The study by Vescovi *et al.* (2006:223), however, found that defenders (67 kg) had higher body mass values than goalkeepers (66.4 kg) and that midfielders (61.3 kg) had the lowest body mass values. This heavier body mass among defenders could be an advantage in defensive actions (Silvestre *et al.*, 2006:179) since slightly elevated levels in lean mass could be beneficial for power activities such as jumping and accelerating and for injury prevention (Vescovi *et al.*, 2006:224). Even though the results of Vescovi *et al.* (2006:224) were not significant, the authors found that the defending players were on average slightly taller and heavier in comparison with the forward and midfield players, and midfielders were on average, the shortest in relation to all the other playing positions. This is in line with studies performed on male players (Reilly *et al.*, 2000:671; Matković *et al.*, 2003:169).

In summary, it is evident from several studies that goalkeepers and defending players tend to be the tallest and heaviest players in teams compared with midfielders and forwards (Sedano *et al.*, 2009:390; Sporis *et al.*, 2011:34; Dillern *et al.*, 2012:45; Milanovic *et al.*, 2012:70). It is further believed that the physical traits observed in midfielders enable them to move more efficiently and to cover longer distances during a match (Hazir, 2010:91). A study by Rienzi *et al.* (2000:167) also noted that the total distance covered among international male soccer players was influenced by body mass ( $p<0.05$ ).

### 2.2.2 Skeletal length and breadth measurements

The morphological characteristics of female soccer players and their performance levels have not been clearly described in literature (Can *et al.*, 2004:480). A limited number of studies have previously focused on the morphological characteristics and differences among female soccer players (Withers *et al.*, 1987; Can *et al.*, 2004; Sporis *et al.*, 2007; Mujika *et al.*, 2009; Adhikari & Nugent, 2014; Nikolaidis, 2014). The players represented different levels of play, including junior club (Adhikari & Nugent, 2014), second division (Mujika *et al.*, 2009), senior club (Nikolaidis, 2014) and senior elite or first division (Withers *et al.*, 1987; Can *et al.*, 2004; Sporis *et al.*, 2007; Mujika *et al.*, 2009).

An average leg length of 81 cm have been reported for senior female soccer players participating on national and regional levels respectively (Sedano *et al.*, 2009:390) and 100 cm (Jelaska *et al.*, 2015:70), 94 cm (Sporis *et al.*, 2007:93) and 84 cm (Can *et al.*, 2004:481) for elite players. Sporis *et al.* (2007:93) found goalkeepers to have the longest leg lengths (100 cm) compared with the other playing positions, which is not surprising since they were the tallest among all the players in the study. The shortest leg lengths were reported for midfielders (93 cm), who were also found to be the shortest players among the group assessed, with slightly longer leg lengths being reported for forwards (93 cm) and defenders (94 cm) (Sporis *et al.*, 2007:93). However, none of these results showed any differences among playing positions ( $p=0.359$ ) (Sporis *et al.*, 2007:93). In contrast to the results reported by Sporis *et al.* (2007:93), Sedano *et al.* (2009:391) measured the second-shortest average leg length in goalkeepers (79 cm) and the shortest in the forwards (78 cm). Even though goalkeepers tend to be taller than other players (Vescovi *et al.*, 2006:223; Sporis *et al.*, 2007:93; Milanovic *et al.*, 2012:70), the goalkeepers in this particular group were representative of the shorter players, being only slightly taller than the forward and full-back players, thereby explaining the shorter leg lengths measured (Sedano *et al.*, 2009:390). However, the highest average leg-length measurements were demonstrated among the centre-back players (84 cm), the players strategically placed in front of the goalkeepers to assist in defending the goal area (Sedano *et al.*, 2009:391). Arm lengths did not differ among the goalkeepers (75 cm), forwards (71 cm), midfielders (71 cm) and defenders (71 cm) in the study conducted by Sporis *et al.* (2007:93). Similar arm lengths of 70 cm and 73 cm were reported by Can *et al.* (2004:481) and Jelaska *et al.* (2015:70) respectively for elite players. Owing to the height of the goalkeepers, it is expected that they would have longer leg and arm lengths in comparison with players in other positions (Sporis *et al.*, 2007:94). Nonetheless, higher body mass, taller stature and longer leg and arm lengths among goalkeepers are considered to contribute to their self-confidence when trying to cover and defend the broad area between the goalposts (Matković *et al.*, 2003:171).

A study conducted by Can *et al.* (2004:481) compared females participating in a top-class Turkish team with sedentary female students and found that the circumferential measurements for muscle girths of the soccer players compared with the sedentary females' chest measurements (85 cm compared with 82 cm) and thigh measurements (51 cm compared with 49 cm) were higher ( $p < 0.05$ ). Abdomen, relaxed arm, flexed arm, forearm and calf measurements of 75 cm, 25 cm, 27 cm, 22 cm and 35 cm were recorded for the Turkish elite female soccer players respectively (Can *et al.*, 2004:481). The soccer players also had larger biacromial (35 cm compared with 34 cm), knee (9 cm compared with 8 cm) and ankle (6.4 cm compared with 6 cm) circumferential measurements than the sedentary females (Can *et al.*, 2004:481). Similar measurements of the biacromial (36 cm) and knee (9 cm) circumferences were also noted among elite Croatian female players (Sporis *et al.*, 2007:93). Elbow circumferences of 6 cm were reported by Can *et al.* (2004:481), Sporis *et al.* (2007:93) and Jelaska *et al.* (2015:70) respectively, as well as wrist measurements of 5 cm reported by Can *et al.* (2004:481) and Jelaska *et al.* (2015:70) respectively. Can *et al.* (2004:483) explained that it was anticipated that the knee and ankle circumferences of the soccer players would be greater than those of the sedentary females because soccer demands a greater stabilisation in lower-limb articulation and requires a large bone diameter. Sporis *et al.* (2007:94) also mentioned that the higher circumferential measurements in the thighs of soccer players are possibly due to greater muscle mass versus less fat.

Sporis *et al.* (2007:93) further classified the players according to positions and found that upper arm, forearm and thigh circumferential measurements were highest in goalkeepers (28 cm, 23 cm, 59 cm), followed by forwards (28 cm, 23 cm, 57 cm). Similar values, including the lowest values, were found among midfielders (25 cm, 23 cm, 56 cm) and defenders (26 cm, 23 cm, 55 cm) (Sporis *et al.*, 2007:93). None of these results showed any differences in terms of the playing positions (Sporis *et al.*, 2007:93). Sporis *et al.* (2007:93) also reported the highest calf measurements in midfielders, forwards and defenders (36 cm), while goalkeepers (34 cm) were found to have the lowest calf measurements. Biacromial and knee circumferences were also higher in goalkeepers (39 cm and 9 cm) (Sporis *et al.*, 2007:93). This was followed by forwards (37 cm and 9 cm), with the lowest values recorded for midfielders (35 cm and 9 cm) and defenders (36 cm and 9 cm) (Sporis *et al.*, 2007:93). Elbow girth measurements of 7 cm and 6 cm were also reported for goalkeepers and outfield playing positions respectively (Sporis *et al.*, 2007:93). Sporis *et al.* (2007:94) concluded that the larger thigh-girth measurement in goalkeepers could be due to their specific role of defending the goal. In this particular study, the lower measurements consistently found among midfield players could be related to their

positional role since these players were demonstrated to be shorter, to weigh less and to have the lowest body fat percentage (BF%) (Sporis *et al.*, 2007:93).

### 2.2.3 Skinfold measurements and body fat percentage

A low relative BF% is desirable for successful competition in almost any sport (Can *et al.*, 2004:483). A certain amount of fat is required for the maintenance of body metabolism; however, excess adiposity has a negative influence on soccer performance (Anwar & Noohu, 2016:142; Slimani *et al.*, 2017). Milanovic *et al.* (2012:71) highlighted the importance of body mass for female soccer players since an increase in body fat appears to result in a proportional loss in muscle mass. This appears to result in insufficient development of explosive strength, which is important in the performance of actions such as movement direction changes, jumps and sprints (Milanovic *et al.*, 2012:71). In agreement, Anwar and Noohu (2016:141) argued that a negative correlation exists between BF% and vertical jump height, and that a positive correlation exists between BF% and sprint performance.

Sum of skinfolds provides an index to determine adiposity, with particular skinfold determinations supplying information concerning local fat depots and fat distribution in the body (Garrido-Chamorro *et al.*, 2012:804). Differences exist among studies on female soccer players in terms of number of skinfold sites and circumferential measurements taken in order to determine BF%. Five skinfolds (triceps, subscapular, biceps, supraspinale, calf) and four girths (arm, calf, humerus, femur) have been used for Canadian sub-elite players (Adhikari & Nugent, 2014:15), whereas six skinfolds (triceps, subscapular, suprailiac, abdomen, front thigh, medial calf) and two diameters (wrist, femur) have been used for Spanish elite players (Sedano *et al.*, 2009:388). In a study conducted by Can *et al.* (2004:481), seven skinfolds (triceps, biceps, subscapular, chest, midaxillar, abdominal, suprailiac, anterior thigh, medial calf) and seven diameters (biacromial, biiliac, bitrochanteric, wrist, elbow, knee, ankle) were used. Nikolaidis (2014:43) made use of ten skinfolds (cheek, wattle, chest I, triceps, subscapular, abdominal, chest II, suprailiac, thigh, calf). Mujika *et al.* (2009:109) reported a difference ( $p < 0.001$ ) in the sum of six skinfolds (triceps, subscapular, suprailiac, abdominal, front thigh, medial calf) between senior first-division (74.4 mm) and junior second-division (95.1 mm) female players. A total of 100 mm (sum of six skinfolds) was reported for elite female soccer players by Garrido-Chamorro *et al.* (2012:807). Five skinfold thicknesses at different sites reported for Canadian female soccer players at junior sub-elite level demonstrated values for triceps (9.4 mm), subscapular (8.9 mm), biceps (9.1 mm), supraspinale (10.0 mm) and the calf (10.9 mm) (Adhikari & Nugent, 2014:15). Jelaska *et al.*

(2015:70) alternatively reported values for triceps (16.9 mm), the back (11.3 mm), abdominal (20.5 mm) and calf (13.1 mm) skinfold sites.

Values for average BF% in the range of 18.5–20.6% have been reported for elite female soccer players (Can *et al.*, 2004:481; Sedano *et al.*, 2009:390; Krusturup *et al.*, 2010:438; Bendiksen *et al.*, 2013:1432), with an average range of 12.7–27.6% reported in the study by Krusturup *et al.* (2010:438) (See Table 1). Higher BF% values of 23% (Nikolaidis, 2014:43), 22.1% (Adhikari & Nugent, 2014:15) and 24.7% (Hasegawa & Kuzuhara, 2015:52) were reported for sub-elite female players. In a study conducted by Todd *et al.* (2002:376), comparisons were made among female players participating on different levels, and it was found that the international players had a lower BF% value (22.9%) compared with the Premier League (23.9%) and Regional League players (25.5%). In addition, BF% values of 15.5% and 18.4% were reported by Gravina *et al.* (2011:1346) for two groups of players participating on different elite levels (Spanish First Division and Spanish Second Division respectively). In relation to these results, Spanish national-level players also had a lower BF% value (20.1%) compared with first-division players (24.6%) (Sedano *et al.*, 2009:390). Evidence, therefore, indicates that players participating on a higher level possess a lower BF% (Sedano *et al.*, 2009:390; Gravina *et al.*, 2011:1346).

Sedano *et al.* (2009:391) grouped the players in their sample into a wider classification in terms of playing positions and reported a large variety of BF% values: goalkeepers (26.5%); full-backs (18.1%); centre-backs (25.3%); midfielders (20.2%); wide midfielders (20.9%); and forwards (21.3%). Much lower BF% values than those noted in the study by Sedano *et al.* (2009:391) were reported by Sporis *et al.* (2007:93), with the lowest values measured in midfielders (12.6%) and slightly higher values reported for goalkeepers (13.7%), forwards (14.3%) and defenders (16.8%). Similar to the studies of Sporis *et al.* (2007:93) and Sedano *et al.* (2009:391), Todd *et al.* (2002:377) found that midfielders had the lowest BF% (24.0%). This was closely followed by defenders (24.2%) and forwards (24.3%), with the highest values measured among goalkeepers (26.3%) (Todd *et al.*, 2002:377). Sporis *et al.* (2007:94) and Silvestre *et al.* (2006:179) explained that the low BF% value presented by midfielders could be due to the position-specific task of connecting two lines of play that midfielders must accomplish in a soccer match consisting of defence and attack. The higher BF% usually reported for goalkeepers was previously explained as being due to a lower aerobic demand specific to the position (Todd *et al.*, 2002:379) and a decrease in energy expenditure during training and matches (Silvestre *et al.*, 2006:179). According to Datson *et al.* (2014:1229), it can be speculated that the positional differences demonstrated in recent studies are a result of increased training specificity for playing positions

or that players with particular anthropometric characteristics are assigned to certain playing positions.

It is apparent from the sources cited in the above discussion that BF% values vary considerably across studies. However, it is important to note that the type of measurement method used for body fat may account for discrepancies among the reported values (Martínez-Lagunas *et al.*, 2014:259).

#### **2.2.4 Somatotype characteristics**

Somatotype is the basic classification of physical characteristics and body type (Hazir, 2010:84). Somatotype has become a noteworthy field of interest for many exercise and sport scientists and is considered one of the factors that predisposes an individual to potential high performance achievement (Can *et al.*, 2004:482). Body shape can be defined in terms of three somatotype components, namely endomorphy, mesomorphy and ectomorphy (Gil *et al.*, 2007:438), and is expressed by a three-number rating (Withers *et al.*, 1987:575). These three components are identified in the classical Heath-Carter anthropometric somatotype method as relative fatness (endomorph), musculoskeletal (mesomorph) and linearity (ectomorph) (Hazir, 2010:84). Somatotyping has also been used by dieticians and nutritionists in the past few years for diet preparation according to the endomorphic, mesomorphic and ectomorphic components (Adhikari & Nugent, 2014:14).

Mesomorphy is usually the most predominant somatotype component in soccer players (Can *et al.*, 2004:484). A greater mesomorphic rating or fat-free mass suggests a larger relative muscle mass with which to initiate and sustain movement (Withers *et al.*, 1987:580). Can *et al.* (2004:484) also explained that a general increase in the mesomorphic component can be the product of regular training and can result in a decrease of the endomorphic component, thus increasing the level of performance. The mesomorphic component is an important factor in soccer for strength, with a prevalence of ectomorphic components (Adhikari & Nugent, 2014:17). Adhikari and Nugent (2014:17) further explained that an ectomorphic mesomorph body type is more desirable for speed and endurance and strong muscle power. A lower endomorphic component indicates that the fat mass is lower, thus enhancing acceleration in activities such as running and jumping (Withers *et al.*, 1987:579). Thus, body types in which a high muscle content is prevalent can be advantageous to soccer players due to the high intensity and the repetitive and intermittent type of activity required in matches (Hazir, 2010:90). An inclination in the endomorphic component may be viewed as an indicator of under-training and therefore, regular somatotype assessment is recommended to monitor and control body fat content (Hazir, 2010:92).

Can *et al.* (2004:481) reported somatotype values of 3.0 (endomorph), 3.5 (mesomorph) and 2.4 (ectomorph) for a group of professional female soccer players in the Turkish highest division. The players were compared to sedentary females, and a somatotype of 3.5–3.3–2.9 was reported for the sedentary group, indicating that the soccer players showed more mesomorphic and less endomorphic and ectomorphic components than the sedentary group, who were also primarily classified as endomorphs (Can *et al.*, 2004:481). Furthermore, the study found that the players who achieved the best scores in the strength and power assessments were in the endomorphic mesomorph group (Can *et al.*, 2004:484). Adhikari and Nugent (2014:17) reported a balanced mesomorph (3.0–3.9–2.6) somatotype among their group of female Canadian soccer players; however, the group comprised junior players. These values were lower than those previously reported by Withers *et al.* (1987:578) for elite Australian female soccer players (4.2–4.6–2.2), who displayed an endomorphic mesomorph somatotype (Table 2). A study by Nikolaidis (2014:43), however, reported a mesomorphic endomorph somatotype (5.2–4.6–2.0) for sub-elite Greek female players, thus indicating the highest value in the endomorphic component. The higher mesomorphic values recently displayed by male defenders, midfielders and forwards are explained as possibly being the result of intensive training, exhaustive running and frequent movement during game situations since goalkeepers demonstrated higher endomorphic values (Saha *et al.*, 2014:39).

**Table 2: Somatotype of female soccer players**

Author	Country & competition level	n	Endomorphy	Mesomorphy	Ectomorphy
Adhikari and Nugent (2014:15)	Canadian club level	18	3.0±0.8	3.9±0.8	2.6±1.0
Nikolaidis (2014:43)	Greek Amateur club level	54	5.2±1.5	4.6±1.3	2.0±1.2
Can <i>et al.</i> (2004:482)	Turkish highest division	17	3.0±0.8	3.5±0.9	2.4±0.9
Withers <i>et al.</i> (1987:578)	South Australian team	11	4.2±1.3	4.6±1.0	2.2±1.2

Data are expressed as mean ± standard deviation

Morphological factors make an important contribution to successful sports performance (Nikolaidis & Karydis, 2011:80). Even though Sporis *et al.* (2007:94) reported no differences in the morphological variables of female soccer players according to their playing positions, the

study concluded that morphological characteristics are important factors to consider for playing positions, particularly with regard to goalkeepers. However, Sporis *et al.* (2007:94) also emphasised the importance of motor and physiological abilities and their influence in the selection process. The study by Mujika *et al.* (2009:111) combined their analyses for male and female players and noted that the Yo-Yo intermittent recovery level 1 (Yo-Yo IR1) performance was negatively related to the sum of skinfolds for the pooled data. However, it was positively related to body mass and height (Mujika *et al.*, 2009:111), thereby suggesting that body composition plays a role in intermittent, high-intensity, aerobic activity. Therefore, it can be concluded that lean body mass seems to affect the distance covered in the Yo-Yo IR1, lending an anthropometric-based explanation to the lower performance in the female groups (Mujika *et al.*, 2009:111). It appears that players with a somatotype displaying a combination of high muscularity and low adiposity have the advantage in a match of being more movable when competing for ball possession (Strudwick *et al.*, 2002:241). If a relationship exists between somatotype and performance, a need exists for more information regarding the somatotype of female soccer players and the enhancement of performance levels (Can *et al.*, 2004:480).

In conclusion, several authors have found positional differences in the anthropometric profiles of female players, indicating a trend for goalkeepers and defenders to be taller and heavier than forwards and midfielders and to possess the highest BF%, with midfielders being distinctly shorter and lighter with the lowest BF% values (Vescovi *et al.*, 2006:223; Sedano *et al.*, 2009:391; Sporis *et al.*, 2011:34; Dillern *et al.*, 2012:45; Haugen *et al.*, 2012:341; Milanovic *et al.*, 2012:70). The smaller stature of midfielders is not viewed as a hindrance to success since it may play a central part in the tactical role allocated to these players (Strudwick *et al.*, 2002:241). Also, despite the fact that the demands of goalkeepers are different to other positions, this should not be used as an excuse for paying less attention to their aerobic capacity due to the fact that excessive body fat is seen as a critical negative factor related to performance (Gil *et al.*, 2007:444).

Morphological characteristics are, therefore, apparent for specific positions in the team, especially with regard to goalkeepers (Sporis *et al.*, 2007:94). Martínez-Lagunas *et al.* (2014:263) nonetheless suggest that future studies consisting of larger sample sizes should explore the extent to which players' anthropometrical characteristics influence role selection in female soccer. Strudwick *et al.* (2002:247), however, claim that both anthropometric and performance variables are related to the positional role of individual players and therefore, the establishment of fitness profiles should also form part of the holistic approach to prepare players for elite match play. It is, therefore, suggested that not only morphological characteristics but also physiological characteristics applicable to the sport and playing position are critical in order to compete at an

elite level (Hazir, 2010:83). It is believed that a link exists between the anthropometric characteristics and performance in soccer (Dillern *et al.*, 2012:47) and therefore, an understanding of a range of performance variables is important.

### **2.3 Performance variables associated with successful participation in female soccer**

The profiles of players and their development towards becoming elite performers have emerged as topics of decisive interest in the soccer milieu (Dillern *et al.*, 2012:43). Soccer places diverse physical demands on players during a match (Clark, 2007b:453), and players accordingly require good physical condition to perform multidirectional movement patterns and phases involving rapid stops (Grygorowicz *et al.*, 2013:5). The sport is characterised by its participants executing short bursts of maximal or near-maximal actions interspersed with brief periods of low-intensity activities (LIA) that rely mainly on aerobic energy metabolism (Miller *et al.*, 2007:48). Explosive power is also often required in winning critical moments of a match (Clark, 2007b:453). Individual differences exist in regard to the physical demands placed on players during matches, which are believed to be partly related to the players' positions in the team (Bangsbo *et al.*, 2006:666). Sport scientists and trainers are often tasked with maximising physical performance, with the ultimate aim of obtaining higher success in competitions (Clark, 2007a:41). For this reason, the evaluation of a player's aerobic and anaerobic capacity is important because these variables may determine the outcome of a match (Bangsbo *et al.*, 2008:38). However, due to time constraints and restricted resources available in female soccer, physical conditioning is often conducted in team sessions, with coaches attempting to optimise group conditioning in the limited time available (Polman *et al.*, 2004:192). The following section investigates the aerobic and anaerobic performance variables of female soccer players according to playing positions and examines the relationships between these individual components.

#### **2.3.1 Importance of aerobic fitness and means of measurement in soccer**

Optimal aerobic fitness is a prerequisite for elite soccer players (McMillan *et al.*, 2005:273). Soccer is mainly dependent upon aerobic metabolism due to the duration of a match being 90 minutes of play (Casajus, 2001:463; Stølen *et al.*, 2005:503). Elite female players cover an average of 8–11 km during a match (Krustrup *et al.*, 2005; Mara *et al.*, 2017; Ramos *et al.*, 2017; Trewin *et al.*, 2018). This is similar to or slightly lower than the distances reported for elite male players, which range between 10 km and 12 km on average (Stølen *et al.*, 2005:503; Di Salvo *et al.*, 2007:223; Bradley *et al.*, 2010:2345). The distance covered during a match thus indicates that aerobic metabolism is the most important source of energy for soccer players (Shalfawi *et al.*, 2014:19). Soccer players consequently require a high level of aerobic fitness to cope with the

demands of the game and to allow for their technical and tactical skills to be used to their full potential throughout the match (Polman *et al.*, 2004:191). Teams with a higher aerobic endurance capacity are more likely to exert their dominance and as a result, be more successful (Clark, 2007a:44). Players with a higher aerobic fitness also showed a 20% increase in total distance covered during competitive match play, a 23% increase in involvement with the ball and a 100% increase in the number of sprints performed by each player following an intervention (Helgerud *et al.*, 2001:1928).

Maximal oxygen uptake ( $\dot{V}O_{2max}$ ) is defined as the maximum volume of oxygen that the body consumes per minute during endurance exercise (Coutts & Abt, 2005:2). These  $\dot{V}O_{2max}$  values can be expressed absolutely as litres per minute (L/min) when total power output is an important factor or relative to the body mass per minute (mL/kg/min) for activities when body mass should be considered (Duthie *et al.*, 2003:978). In addition,  $\dot{V}O_{2max}$  is an indirect indicator of soccer match performance since an increase in  $\dot{V}O_{2max}$  will typically result in an increase in the anaerobic threshold (Miller *et al.*, 2007:48). Miller *et al.* (2007:48) further pointed out that the ability to sustain high-intensity (HI) aerobic activity at or near the lactate threshold should be a primary consideration when designing strength and conditioning training programmes for soccer players.

A range of field and laboratory tests are used to evaluate aerobic fitness (Metaxas *et al.*, 2005:79). These tests, which are used in the assessment of both male and female soccer players, include a laboratory incremental treadmill running test (Krustrup *et al.*, 2005; Miller *et al.*, 2007; Rampinini *et al.*, 2010; Sporis *et al.*, 2011), a 20-m continuous multistage shuttle run test (Vescovi *et al.*, 2006; Shalfawi *et al.*, 2014), and the Yo-Yo intermittent recovery (Yo-Yo IR) tests (Krustrup *et al.*, 2005; Mujika *et al.*, 2009; Chaouachi *et al.*, 2010; Rampinini *et al.*, 2010; Milanovic *et al.*, 2012; Bradley *et al.*, 2013). It is important to note that most tests are continuous, whereas many sports, including soccer, involve intermittent exercise, and performance is related to the player's ability to perform intense exercise repeatedly (Krustrup *et al.*, 2003:697).

Stølen *et al.* (2005:529) explained that a standardised laboratory treadmill test performed by running on a motor-driven treadmill is used for soccer players and involves direct measurements to determine accurate  $VO_2$  using advanced equipment for gas and ventilator analysis (Chamari *et al.*, 2005:24). While the results gained from laboratory testing are considered to be the best for aerobic assessment, trained personnel and expensive equipment are required to conduct these time-consuming assessments (Castagna *et al.*, 2006:320), making them inaccessible for regular use, even for clubs with strong financial support (Turner *et al.*, 2011:31). It is further mentioned that athletes are sometimes reluctant to be assessed in a laboratory (Impellizzeri *et al.*, 2005:584).

In addition, these tests are not very sport-specific (Deprez *et al.*, 2014:903) since in all team sports involving the use of a ball, it is difficult to propose physical tasks in a laboratory context that could be relevant to real action (Casajus, 2001:464). The majority of professional soccer matches and training sessions take place on a natural grass field and hence, it is important to obtain specific performance results relative to the surface on which the players participate (O'Reilly & Wong, 2012:1035).

The exclusion of direct  $\dot{V}O_{2max}$  measurement dictates that the next best alternative for assessment is based on the closeness of the relationship between the test and  $\dot{V}O_{2max}$ , the specificity of the test to performance and the ease of assessing large subject populations (Pearson *et al.*, 2006:281). This led to the design of valid and reliable field tests that have become popular among coaches and players due to their simplicity, time efficiency and minimal equipment requirements (Turner *et al.*, 2011:31). A range of beep tests are available (Turner *et al.*, 2011:31), with the 20-m shuttle run test of Léger and Lambert (1982:2) being the most renowned to estimate maximum aerobic power with an indirect method from which  $\dot{V}O_{2max}$  can be predicted. However, O'Reilly and Wong (2012:1033) claim that this particular test does not closely represent the activity profile of a soccer match and may not be ideally suited for the assessment of elite-level players.

The more applicable and soccer-specific 20-m shuttle run tests known as the Yo-Yo IR tests, which are representative of the match activities of soccer players, are often advised for teams without access to laboratory tests for  $\dot{V}O_{2max}$  (Stølen *et al.*, 2005:529). Due to the specificity and practicality of the Yo-Yo IR tests, they have been widely applied in many team sports and have rapidly become some of the most intensively studied fitness tests in sport science (Bangsbo *et al.*, 2008:38). Two levels of the Yo-Yo IR test have been developed: the Yo-Yo intermittent recovery test level 1 (Yo-Yo IR1) and the Yo-Yo intermittent recovery test level 2 (Yo-Yo IR2) (Bangsbo *et al.*, 2008:38). The Yo-Yo IR1 starts at a lower speed and involves a more moderate increase in speed than the Yo-Yo IR2 (Bangsbo *et al.*, 2008:38). According to Bangsbo *et al.* (2008:38), the Yo-Yo IR1 test lasts between 10 min and 20 min for a trained individual and mainly focuses on endurance capacity. The Yo-Yo IR2 test lasts between 5 min and 15 min and evaluates a trained individual's ability to perform a repeated intense exercise bout with a high anaerobic energy contribution (Bangsbo *et al.*, 2008:38). An earlier study found that the maximal heart rate ( $HR_{max}$ ) reached during the Yo-Yo IR1 test was  $99 \pm 1\%$  of the  $HR_{max}$  reached during a graded treadmill test (Krustrup *et al.*, 2003:700). Thus, the Yo-Yo IR1 test is also useful in

establishing a player's  $HR_{max}$  since it stimulates the aerobic system maximally (Bangsbo *et al.*, 2008:39).

Based on the results of different studies, a  $\dot{V}O_{2max}$  in the range of 48.7–56.8 ml/kg/min can be expected for female soccer players, depending on competitive level (Krustrup *et al.*, 2005:1729; Krustrup *et al.*, 2010:438; Ingebrigtsen *et al.*, 2011:3354; Dillern *et al.*, 2012:45; Haugen *et al.*, 2014:517). In considering different playing positions, neither Vescovi *et al.* (2006:225) (estimated  $\dot{V}O_{2max}$  values) nor Ingebrigtsen *et al.* (2011:3355) (direct  $\dot{V}O_{2max}$  measurement) nor Dillern *et al.* (2012:45) (direct  $\dot{V}O_{2max}$  measurement) found any significant differences ( $p \leq 0.05$ ) in  $\dot{V}O_{2max}$  among the different positions. Even though not significant, these studies did find that midfielders achieved the highest  $\dot{V}O_{2max}$  scores, ranging between 50.5 ml/kg/min (Vescovi *et al.*, 2006:224), 55.3 ml/kg/min (Ingebrigtsen *et al.*, 2011:3354) and 53.8 ml/kg/min (Dillern *et al.*, 2012:45). It is also evident that the players competing on a higher level (Ingebrigtsen *et al.*, 2011:3354; Dillern *et al.*, 2012:45) achieved a higher  $\dot{V}O_{2max}$  than the players on a lower level (Vescovi *et al.*, 2006:224). Reports by Haugen *et al.* (2014:519), however, noted that midfielders (57.7 ml/kg/min) had a higher ( $p=0.48$ )  $\dot{V}O_{2max}$  in comparison with goalkeepers (52.3 ml/kg/min) in a study conducted over an 18-year period using direct  $\dot{V}O_{2max}$  measurements. Further result analysis of elite Norwegian first- and second-division female players in the study by Ingebrigtsen *et al.* (2011:3354) revealed that forwards (52.9 ml/kg/min) had the second-highest  $\dot{V}O_{2max}$  values, with the lowest values measured among the defenders (51.9 ml/kg/min) and goalkeepers (50.7 ml/kg/min). A similar trend was reported for Norwegian third-division players, with the forwards (53 ml/kg/min) achieving higher values than the defenders (52.1 ml/kg/min) and goalkeepers (48.7 ml/kg/min) (Dillern *et al.*, 2012). This trend was also evident among sub-elite female players, with results of 49.4 ml/kg/min, 47.6 ml/kg/min and 47.1 ml/kg/min being reported for forwards, defenders and goalkeepers respectively (Vescovi *et al.*, 2006:224). It is, therefore, evident that midfield and forward players tend to possess a higher level of aerobic fitness that may be linked to their positional demands on the field (Haugen *et al.*, 2014:519).

The Yo-Yo IR1 test has high reproducibility ( $r=0.98$ ) and is associated with match-related demands ( $r=0.53$ – $0.71$ ) of male soccer players (Krustrup *et al.*, 2003:703). The Yo-Yo IR1 test is frequently used to evaluate a player's ability to perform repeatedly during intervals over a prolonged period of time (Metaxas *et al.*, 2005:80). According to Castagna *et al.* (2009:1958), the Yo-Yo IR1 is also a valid test for assessing match-related physical fitness in young male soccer players. Performance in the Yo-Yo IR1 was demonstrated to be related to high-intensity activity (HIA) ( $r=0.77$ ;  $p < 0.00001$ ), high-intensity running (HIR) ( $r=0.71$ ;  $p=0.00003$ ) and total distance

covered ( $r=0.65$ ;  $p=0.002$ ) during a match (Castagna *et al.*, 2009:1957). Among elite female soccer players, Yo-Yo IR1 performance correlated positively with HIR ( $r=0.76$ ;  $p=0.002$ ) and total distance covered ( $r=0.56$ ;  $p=0.038$ ) during a match (Krustrup *et al.*, 2005:1245). The study concluded that the Yo-Yo IR1 test is a good predictor of the ability of elite female soccer players to perform HIR throughout matches (Krustrup *et al.*, 2005:1245). It is suggested that an average distance of 1 200 m may be considered the reference standard for classifying elite female soccer players (Mujika, Santisteban *et al.*, 2009:111) (Table 3).

**Table 3: Distances obtained during the Yo-Yo intermittent recovery tests among female soccer players**

Author	Country & competition level	Test method	Distance (m)
Hasegawa and Kuzuhara (2015:53)	Japanese Aichi sub-elite 1 <sup>st</sup> Division	Yo-Yo IR1	889.5±321.7 760±215.4 (FW) 820±316.7 (MF) 1095±324.2 (DF) 600±169.7 (GK)
Bendiksen <i>et al.</i> (2013:1432)	Norwegian 1 <sup>st</sup> Division	Yo-Yo IR1	1232±244
Milanovic <i>et al.</i> (2012:70)	Serbian A-National Team	Yo-Yo IR1	Range 880–930 780±84.8 (GK)
Krustrup <i>et al.</i> (2010:438)	Danish top league	Yo-Yo IE2	1213±90
Mujika <i>et al.</i> (2009:110)	Spanish 1 <sup>st</sup> Division	Yo-Yo IR1	1224±255 (outfield players)
Mujika <i>et al.</i> (2009:110)	Spanish 2 <sup>nd</sup> Division	Yo-Yo IR1	826±160 (outfield players)
Krustrup <i>et al.</i> (2005:1245)	Danish highest division	Yo-Yo IR1	1379 (range 600–1960)

Data are expressed as mean ± standard deviation. Abbreviations: FW: Forwards; MF: Midfielders; DF: Defenders; GK: Goalkeepers; Yo-Yo IR1: Yo-Yo Intermittent Recovery level 1 test; Yo-Yo IE2: Yo-Yo Intermittent Endurance level 2 test

The aerobic capacity of soccer players is dependent upon the level of competition (Dillern *et al.*, 2012:47). Average distances of 1 379 m, 1 232 m and 889 m for the Yo-Yo IR1 test have been reported by Krustrup *et al.* (2005:1245), Bendiksen *et al.* (2013:1432) and Hasegawa and Kuzuhara (2015:53) respectively for Danish elite, Norwegian elite and Japanese sub-elite female players, indicating that players competing on a higher level are capable of producing a better

result in the Yo-Yo IR1 test. Distances recorded for Japanese sub-elite female players indicated that defenders and midfielders ran the longest distances (1 095 m and 820 m respectively) and that the forwards and goalkeepers ran the shortest distances (760 m and 600 m respectively), although the results did not show a statistically significant difference ( $p < 0.05$ ) between any playing positions (Hasegawa & Kuzuhara, 2015:53). Mujika *et al.* (2009:110) also used the Yo-Yo IR1 test and compared two groups of outfield players participating on different levels, namely first and second division. They found that the results obtained for the first-division players (average 1 224 m) differed ( $p < 0.001$ ) from those obtained for the second-division players (average 826 m) (Mujika *et al.*, 2009:110) (See Table 3). Furthermore, it was reported that the results for the Yo-Yo IR1 test for Japanese female sub-elite players were 22% lower than the results for the Under-19 Japanese team players and 25% lower than the results for the Japanese national team players, thus confirming the correlation between the Yo-Yo IR1 test and the competitive level of the players (Hasegawa & Kuzuhara, 2015:55). These results indicate the need to possess a high level of endurance to compete professionally (Mujika *et al.*, 2009:110).

### 2.3.2 Importance of anaerobic fitness variables and means of measurement in soccer

Due to the nature of a soccer match consisting of stop-and-go activities coupled with infrequent stoppages in play, it is important that not only the aerobic but also the anaerobic energy system be well trained in order to maximise HI performance and ensure optimal recovery between bursts of anaerobic activity (Miller *et al.*, 2007:48). Stølen *et al.* (2005:503) maintain that strength and power are equally important for endurance in soccer. In order to perform short sprints, jumps, tackles and dual play, anaerobic energy release is essential with regard to who is sprinting fastest and jumping the highest (Stølen *et al.*, 2005:509). Body movements are further determined by situations within a match, including players from the opposing team with and without the ball, movement of the ball and movement of team players (Kapidžić *et al.*, 2011:29).

Even though assessment protocols typically include laboratory and field tests for the assessment of anaerobic performance characteristics, the use of field tests requires little equipment and involves common movement skills, thereby requiring minimal instruction on proper performance (Vescovi & McGuigan, 2008:97). Laboratory assessments commonly necessitate familiarisation since individuals often lack experience to perform the movements with the correct techniques, thus compromising safety and the accuracy of these particular testing methods (Vescovi & McGuigan, 2008:97). Field tests are, therefore, more sport specific due to their simplicity and the lack of equipment required (Walker & Turner, 2009:53).

Explosive-type actions such as sprinting and jumping are viewed as essential elements for soccer performance (Sedano *et al.*, 2009:388). Sprint bouts during elite male soccer matches have been reported to last 2 s to 4 s on average (Vigne *et al.*, 2010:305). Elite female players have been reported to perform 125 (range: 72–159) HI runs with an average duration of 2.3 s (range: 2–2.4 s) (Krustrup *et al.*, 2005:1244). Previous studies proved that elite players routinely achieve higher scores compared with sub-elite or non-selected players in terms of sprinting and jumping performance of both female (Hoare & Warr, 2000:756; Mujika *et al.*, 2009:110; Sedano *et al.*, 2009:390) and male players (Reilly *et al.*, 2000:698; Cometti *et al.*, 2001:48; Gissis *et al.*, 2006:210). The training of elite players should thus focus on improving their ability to perform intense exercise and to recover rapidly from HI efforts (Bangsbo *et al.*, 2006:670).

### **2.3.2.1 Repeated sprint ability of female soccer players**

Sprinting during a soccer match fluctuates in its intensity in a stochastic manner, thereby requiring a player to perform repeated sprints in any direction (Wragg *et al.*, 2000:77). Repeated-sprint ability (RSA) is described as the ability to perform short-duration sprints (<10 s) with a short recovery time (<30 s) (Bishop & Edge, 2006:373; Mujika *et al.*, 2009:1581) and is broadly accepted as a vital component of HI intermittent sports such as soccer (Gabbett, 2010:1191). Soccer requires players to perform a number of short sprints, interspersed with periods of low-to-moderate activity or passive rest (Bishop & Edge, 2006:373; Mujika *et al.*, 2009:1581). Spencer *et al.* (2004:846) define an RSA bout as a minimum of three sprints, with an average recovery duration of less than 21 s between sprints. A review by Spencer *et al.* (2005:1028) on sprinting during field-based team sports concluded that the mean duration of HI movements is 2.7–4.4 s with a recovery duration of 40–70 s. The review also confirmed that even though it is difficult to compare studies due to the differences in methodologies used, the mean distance (10–20 m) and duration (2–3 s) of sprints during field-based team sports are relatively consistent (Spencer *et al.*, 2005:1031).

With reference to the criteria for RSA provided by Spencer *et al.* (2004:846), a study on Australian female soccer players participating in international matches showed a number of 4.8 sprint bouts per player during a match (Gabbett & Mulvey, 2008:549). A mean number of 3.4 sprints (ranging between 3 and 6 sprints) were performed within a repeated-sprint bout, and recordings of 5 sprints on four occasions and 6 sprints on two occasions were also reported (Gabbett & Mulvey, 2008:549). An average sprint duration of 2.1 s and an average maximal sprint duration of 2.9 s were recorded, as well as an average recovery time of 5.8 s between sprints, with most recovery time being active in nature (Gabbett & Mulvey, 2008:549). Due to the unpredictable nature of

team sports, short phases of repeated-sprint activity may be required on numerous occasions throughout a match, and even though it is probable that this type of activity only contributes a small proportion to the overall motion activity during competition, it may be critical to the end result of a match (Spencer *et al.*, 2005:1030).

The RSA field test is believed to represent a valid measure of anaerobic soccer performance (Sporis *et al.*, 2008:559) due to its high reliability and validity (Wragg *et al.*, 2000:80). A wide range of testing protocols exist for determining the RSA of team sport athletes (Bishop & Spencer, 2004:2; Polman *et al.*, 2004:196; Clark, 2007a:42; Sporis *et al.*, 2008:561; Mujika *et al.*, 2009:1583; Gabbett, 2010:1192; Krusturp *et al.*, 2010:438; Jones *et al.*, 2013:2; Shalfawi *et al.*, 2014:20). Comparisons between studies are difficult due to variations in mode of exercise, duration of sprints, number of sprint repetitions, recovery type and training status of the players (Spencer *et al.*, 2005:1039). Spencer *et al.* (2005:1039) analysed different studies that assessed RSA and concluded that a protocol involving six to seven sprints may best represent an intense bout of RSA specific to field-based team sports during competition. In a RSA test that consisted of seven 30-m sprints (with 30 s recovery), elite Norwegian female players achieved an average time of 5.0 s, an average fastest time of 4.9 s and an average total time of 35.2 s (Shalfawi *et al.*, 2014:21).

Krusturp *et al.* (2010:438) examined the effect of fatigue on elite Danish female players by conducting a RSA test consisting of three 30-m sprints (with 25 s active recovery) before and after a match. An average sprint time of  $4.9 \pm 0.1$  s was reported for the RSA test conducted before the match, and a slower time ( $p < 0.05$ ) of  $5.1 \pm 0.1$  s was reported for the RSA test conducted after the match, consequently establishing that fatigue has a negative influence on sprinting performance (Krusturp *et al.*, 2010:439). Gabbett (2010:1193) developed a game-specific test for RSA of elite female soccer players involving maximal effort accelerations, decelerations and active recovery in an attempt to reflect the most extreme demands of international competition. The study results confirmed that the developed test for RSA is a valid and reliable test (ICC = 0.91; TEM = 1.5%) to assess RSA in elite female players (Gabbett, 2010:1193). The reported results also indicated that players participating at national level (20.9 s) performed the RSA test faster ( $p < 0.05$ ) than elite players at a lower level (23.3 s) with regard to total time (Gabbett, 2010:1192). A limitation is recognised, however, where fixed recovery periods are imposed between repeated sprints since the patterns of exercise and recovery in team sports are described as random and are influenced by tactical factors and players' ability to select the intensity of their efforts (Girard *et al.*, 2011:678).

A study conducted by Gharbi *et al.* (2015:209) on team-sport male athletes that included soccer players reported a fatigue index (FI) of 3.5% on an RSA test. A similar method was used by Dardouri *et al.* (2014:142), and a FI of 4.1% was reported. Furthermore, an inverse correlation ( $r=-0.57$ ;  $p<0.05$ ) was found between the RSA FI and the  $\dot{V}O_{2max}$  measured, thereby confirming the important role of  $\dot{V}O_{2max}$  in influencing recovery during RSA (Gharbi *et al.*, 2015:210). In addition, an inverse correlation ( $p<0.05$ ) was found between the Yo-Yo IE2 performance and the RSA FI among elite female soccer players ( $r=-0.66$ ;  $p<0.05$ ), although no correlation was found between  $\dot{V}O_{2max}$  and RSA FI (Krustrup *et al.*, 2010:439). It can, therefore, be concluded that the players with the highest Yo-Yo IE2 test scores also had the lowest RSA FI scores, indicating a relationship between training status and fatigue resistance (Krustrup *et al.*, 2010:440).

Goalkeepers are known to perform highly explosive movements such as jumping, diving and catching with short bursts of forward, backward and lateral movements in order to position themselves in an optimal defensive position to protect the goal area (Aziz *et al.*, 2008:835). A study conducted on male players found that goalkeepers (26.0 s) had a slower ( $p<0.01$ ) total sprint time in a RSA test (8 x 20-m sprints; 20 s recovery) compared to outfield players (25.3 s) (Aziz *et al.*, 2008:835). Further analysis among outfield players showed that forwards (24.8 s) produced the fastest RSA total sprint time, which was faster ( $p<0.05$ ) compared with both midfielders (25.5 s) and forwards (24.8 s) (Aziz *et al.*, 2008:835). This is not an unexpected outcome and indicates that RSA is more relevant for outfield players than goalkeepers (Aziz *et al.*, 2008:835).

### 2.3.3 Relationship between aerobic and anaerobic fitness components

Maximal or near-maximal short-duration sprints (1–7 s) combined with brief periods of recovery (rest or low-to-moderate intensity activity) over extensive time periods (60–90 min) are characteristics of most team sports (Bishop & Spencer, 2004:1; Bishop & Edge, 2006:373). Often, the sprints are separated by recovery periods, which are long enough ( $>1$  min) to allow complete or near-complete recovery, thus not influencing sprint performance negatively (Bishop & Edge, 2006:373). Soccer involves repeated sprinting and jogging, which are categorised as HIR (Hasegawa & Kuzuhara, 2015:55). Gabbett (2010:1193) suggested that RSA tests should be conducted in combination with traditional speed tests (e.g. 40-m sprint with splits at 10-m intervals) and maximal aerobic power tests (e.g. multistage fitness test) since RSA is likely to be affected by both speed and maximal aerobic power. A belief exists that a high level of aerobic fitness is important for RSA (Bishop & Edge, 2006:374). However, to date, only a limited number

of studies have reported on the relationship between  $\dot{V}O_{2max}$  and RSA (Krustrup *et al.*, 2010; Jones *et al.*, 2013; Gharbi *et al.*, 2015).

A clearer understanding of factors contributing to fatigue during RSA is the first step in designing training programmes that could delay the onset of fatigue, improve RSA and as a consequence, improve physical match performance (Girard *et al.*, 2011:676). Shalfawi *et al.* (2014:19) highlighted the importance of developing both aerobic capacity and RSA in an attempt to improve overall performance among Norwegian female players and explained that aerobic capacity could play an important role in the recovery between HI sprints during a match. The study found a moderate correlation ( $r=-0.483$ ;  $p\leq 0.01$ ) between the multistage fitness test and the RSA fastest time and also found a large correlation with the RSA mean time ( $r=-0.552$ ;  $p\leq 0.01$ ) and the RSA total time ( $r=-0.552$ ;  $p\leq 0.01$ ) (Shalfawi *et al.*, 2014:22). A study on elite male soccer players also supports the theory that aerobic capacity is a key factor in influencing recovery from RSA (Jones *et al.*, 2013:3). Moderate correlations were found between  $\dot{V}O_{2max}$  and RSA mean time ( $r=-0.655$ ;  $p<0.01$ ) and between  $\dot{V}O_{2max}$  and RSA total time ( $r=-0.591$ ;  $p<0.01$ ) (Jones *et al.*, 2013:3).

Substantial improvements in Yo-Yo IR1 performance have been noted as a result of repeated-sprint training (Shalfawi *et al.*, 2013:36). Evidence provided by Tomlin and Wenger (2002:199) also indicated a relationship between aerobic and anaerobic fitness by proving that players with a higher level of aerobic fitness were better able to maintain their performance over repeated sprints and demonstrated that more oxygen was consumed throughout nine of the ten sprint-recovery bouts. Similarly, a study on junior elite male players reported a higher number of sprints performed during a match by players who possessed a higher  $\dot{V}O_{2max}$ , indicating that improved levels of aerobic fitness enhance the ability to cover a longer running distance at a higher intensity (Helgerud *et al.*, 2001:1930).

Despite the correlations discussed above, conflicting outcomes also exist concerning the relationship between aerobic fitness and RSA (Da Silva *et al.*, 2010:2115). The relationship between aerobic fitness and RSA differs due to the type of study (Da Silva *et al.*, 2010:2116). It was mentioned previously that a correlation does not necessarily indicate cause and effect since there may be other training adaptations associated with an increase in  $\dot{V}O_{2max}$  that can affect RSA (Bishop & Spencer, 2004:1). Da Silva *et al.* (2010:2116) suggested that one of the aerobic variables known as the velocity at the onset of blood lactate accumulation (vOBLA) may be better associated with RSA than  $\dot{V}O_{2max}$ . A relationship was found between vOBLA and RSA mean time ( $r=-0.49$ ;  $p<0.01$ ) (Da Silva *et al.*, 2010:2119). The minimum velocity needed to reach  $\dot{V}O_{2max}$  also

showed a moderate correlation with RSA mean time ( $r=-0.38$ ;  $p<0.01$ ) (Da Silva *et al.*, 2010:2119). The study, however, reported that no association could be found between any of the aerobic variables and RSA fastest time (Da Silva *et al.*, 2010:2119). According to Jones *et al.* (2013:4), studies should not utilise an indirect method of determining  $\dot{V}O_{2max}$  such as a multistage fitness test to determine the relationship between  $\dot{V}O_{2max}$  and RSA because these tests are likely to have a 10–15% inaccuracy. Furthermore, Da Silva *et al.* (2010:2119) are of the opinion that  $\dot{V}O_{2max}$  is a poor indicator of RSA ( $r=0.08$ ). The authors add that the relationship between these two variables may be influenced by the length of sprints performed since there are no reports that indicate  $\dot{V}O_{2max}$  is related to RSA when sprints of less than 40 m or 6 s have been used (Da Silva *et al.*, 2010:2119). It is additionally suggested that anaerobic power (such as the fastest individual sprint time) proves to be the strongest predictor of RSA (Da Silva *et al.*, 2010:2120). According to Da Silva *et al.* (2010:2116), the age and experience level of players should also be considered when making comparisons as these factors may influence the results. In line with these reports, Chaouachi *et al.* (2010:2667) suggested that intermittent HI endurance (Yo-Yo IR1 performance) and RSA performance should be regarded as semi-independent performance variables since only a moderate relationship ( $r=-0.44$ ) could be found between these two variables when measured in elite male soccer players.

Shalfawi *et al.* (2014:22) recently found large correlations between aerobic fitness (multistage fitness test) and both 40-m linear sprint times ( $r=-0.51$ ;  $p\leq 0.01$ ) and 20–40-m sprint times ( $r=-0.595$ ;  $p\leq 0.01$ ) among female players. The study did not find a relationship between aerobic fitness and sprint acceleration time over 0–20 m (Shalfawi *et al.*, 2014:23) although the authors explained that such a relationship was probable because a soccer match involves many high-intensity actions. The addition of HI aerobic interval training can elevate  $\dot{V}O_{2max}$  levels with no negative effect on sprinting performance (McMillan *et al.*, 2005:277). The discrepancies between the results of different studies may be related to differences in the testing protocols used to assess the aerobic and anaerobic fitness components (McMillan *et al.*, 2005:274; Mujika *et al.*, 2009:109; Shalfawi *et al.*, 2014:20). The training status of the players may have also influenced the results of specific conditioning programmes (Shalfawi *et al.*, 2013:39). Furthermore, untrained individuals tend to respond positively to training interventions, thus making the evaluation of training outcomes more complex (Shalfawi, Young *et al.*, 2013:39). The timing of a study in regard to the season of training or competition may also have an influence on the results observed, depending on whether a study is conducted at the beginning of a season, or during the middle or end of a season when players are challenged with a higher competition demand (Shalfawi *et al.*, 2013:40).

The use of aerobic training to improve RSA performance may yield only marginal benefits (Aziz *et al.*, 2000:199). It is suggested that in order to improve RSA, specific training programmes that focus on both aerobic and anaerobic components should be utilised (Da Silva *et al.*, 2010:2120). Player selection and testing together with physical conditioning should reflect the balance between aerobic endurance and anaerobic power and capacity required (Haugen *et al.*, 2014:520).

## 2.4 Technical skill characteristics of female soccer players

Team sports are characterised not only by intermittent HI exercise but also by the contribution of a variety of technical skills (McGregor *et al.*, 1999:895; Russell *et al.*, 2010:1399). Soccer is categorised as a free-flowing game requiring the execution of many aspects of skill in a dynamic context (Ali, 2011:170). Skills such as passing, dribbling and controlling and shooting a ball are essential in a soccer match (Ali, 2011:175), with dribbling and short passes being the most frequently performed skills observed in matches (Bloomfield *et al.*, 2007:69). During high-level matches, there are usually 900–1000 actions performed with the ball and approximately 350 passes with one touch and 150 passes with two touches (Shephard, 1999:758). High levels of technical and tactical skills are, therefore, required for success in a match (Clark, 2007b:454; Impellizzeri *et al.*, 2008:1193; Rampinini *et al.*, 2009:228) although skill assessment is seldom included during fitness evaluations of soccer players (Ali, 2011:170).

A dearth of studies on skill performance in female soccer players exists within published literature, which is remarkable since it is readily acknowledged that the most important component in soccer play is successful skill execution (Ali, 2011:170). O'Reilly and Wong (2012:1030) explained that the assessment of skill plays a large part in conducting player and team evaluations due to the highly competitive nature of elite-level soccer. Russell and Kingsley (2011:525) explained that it is not unexpected that players allocate a large percentage of their training time to improving their skills due to the technical demands of the game and the importance of skilled actions in defining success. However, coaches do not regularly monitor the efficacy of training on technical performance using means other than empirical observations (Russell & Kingsley, 2011:525). O'Reilly and Wong (2012:1030) further suggested that coaches and trainers could greatly benefit from more precise and objective testing procedures, thus positively contributing to the selection of teams in order to gain a competitive edge over opponents.

According to Ali (2011:171), a difference exists between 'technique' and 'skill' in that the assessment of a movement involving the isolation of one component of the game such as shooting or passing from a static and often rested position is an assessment of technique rather

than skill. Ali (2011:171) further explains that skill refers to a player's ability to select and execute the most appropriate technique as determined by the demands of the particular situation. In addition, Ali (2011:171) claims that the ability to make decisions is a fundamental element of skill. Due to the highly competitive character of elite-level sport in general and particularly in soccer, the determination of skill level plays a large role during player assessments (O'Reilly & Wong, 2012:1030). Pedersen *et al.* (2014:962) state that the importance of technical skills in soccer is evident when examining the technical report that is released together with the published statistics regarding tournaments after every FIFA competition.

According to the statistics published by FIFA following the 2015 FIFA Women's World Cup held in Canada, a total of 146 goals were scored during the tournament with an average of 2.8 goals per match compared with 2.6 goals per match in the 2011 FIFA Women's World Cup (FIFA, 2015). The analysis also revealed that an average of 374.3 short passes were performed per match compared with 332.2 short passes in 2011 (FIFA, 2015). In addition, Team USA beat the previous record set in 2011 for the highest-scoring final in the history of the tournament and also surpassed Germany as the top-scoring team in the history of the tournament with 112 goals scored (FIFA, 2015). Following every FIFA tournament, a technical report is published to analyse the progress of the game (FIFA, 2015). The 2015 technical report on the Women's World Cup disclosed that over 70% of goals were scored during transition phases (FIFA, 2015). The report also revealed that more than 80% of goals were scored in front of the goal inside the penalty area and mostly with one touch (FIFA, 2015). The goals were scored after a through-ball from the centre of the field, from a cut-back or from a square ball inside the penalty area (FIFA, 2015).

Recently, studies have focused on skill assessment and its relevance to soccer performance (Lyons *et al.*, 2006; Vaeyens *et al.*, 2006). According to Ali (2011:175), the motor tasks of passing, controlling, dribbling and shooting the ball are essential aspects in soccer. Rampinini *et al.* (2009:232) also identified certain skill parameters that seem to be more relevant for success in top-level professional soccer and include involvements with the ball, short passes, successful short passes, tackles, dribbling, shots and shots on target. Speed, precision and success are also regarded as independent outcome measures in assessing the proficiency of technical skills (Russell *et al.*, 2010:1399).

#### **2.4.1 Technical skill assessment using multifaceted methods**

Soccer players are often required to perform a sequence of skilful actions in a match (Ali, 2011:11). A skilled movement is regarded as a learned ability by a player to select and perform the correct technique depending on the particular situation (Ali *et al.*, 2007:1462). The value of

technical skill assessment should not be underestimated because it could provide important information for talent identification and the design of interventions with the aim of maintaining technical skill performance during a match (Ali, 2011:171). According to Wallace and Norton (2014:223), a large variety of motor skills is required by elite players, allied with rapid information processing and decision-making as the game shifts between attacking and defending activities. A player must thus be able to receive and control a ball and dribble past an opponent before shooting at the goal (Ali, 2011:11). This ability to control the ball is regarded as an important skill (Russell & Kingsley, 2011:525).

Even though a large variety of soccer skill tests are popular and used by coaches, many of these tests have not been validated, which leads to hindered research into soccer skill performance (Ali *et al.*, 2007:1462; Russell *et al.*, 2010:1399). This is related to the difficulty of replicating the complex nature of soccer skills in a way that can be controlled in a laboratory setting (Ali, 2011:171). O'Reilly and Wong (2012:1034) explained that researchers often seek new and enhanced assessment methods to evaluate the ability of players in a more authentic and game-like situation. Thus, as further explained by O'Reilly and Wong (2012:1034), some assessment procedures including elements of both skill and physical ability have been developed. Pedersen *et al.* (2014:963), however, stated that it is not possible to evaluate technical skills in a completely valid manner outside performance in an actual match situation.

According to published literature, various tests have been used in male and female soccer to assess technical skills such as heading (Rösch *et al.*, 2000:34; Pedersen *et al.*, 2014:965), dribbling (Hoare & Warr, 2000:754; Rösch *et al.*, 2000:32), passing (Hoare & Warr, 2000:754; Rostgaard *et al.*, 2008:285; Pedersen *et al.*, 2014:964), shooting (Rösch *et al.*, 2000:33; Starosta *et al.*, 2011:867; Pedersen *et al.*, 2014:965) and juggling (Hoare & Warr, 2000:754; Rösch *et al.*, 2000; Pedersen *et al.*, 2014:964). There is, however, a lack of valid and reliable technical skill tests, thus limiting the amount of research on soccer skill performance (Ali *et al.*, 2007:1462).

A review by Ali (2011:171) reporting on assessment methods for diverse technical skills explained the importance of the different types of validity of these tests. Construct validity means that for a test score to have real meaning, the person believed to have a higher level of the specific characteristic being researched should receive the higher score and thus, it is important to discriminate between different levels of players (Ali, 2011:171). In order to maintain ecological validity, soccer skill tests should attempt to include reactive or perceptual components with technical and physical tasks (Bullock *et al.*, 2012:431). Technical skill tests measuring ecological validity should be focused on skills typically performed during an actual match (Ali, 2011:171).

However, this type of method lacks experimental control as a result of the intricate interactions among players during a match as well as different playing positions (Bullock *et al.*, 2012:431).

A crucial skill that is often measured in technical skill-assessment protocols is dribbling (McGregor *et al.*, 1999:896; Hoare & Warr, 2000:754; Reilly *et al.*, 2000:697; Rösch *et al.*, 2000:32; Stone & Oliver, 2009:165). These tests often involve the traditional techniques of dribbling around cones and conducting the tests in the fastest possible time (McGregor *et al.*, 1999:896; Mujika *et al.*, 2009:1009; Stone & Oliver, 2009:165). Russell *et al.* (2010:1400), however, stated that a shorter time may not necessarily represent a more skilled action and explained that dribbling tests using speed as the sole indicator of success limits ecological validity of technical performance where possession can be won or lost due to a lack of ball control. Passing the soccer ball accurately to a team player is also considered a critical ability required by soccer players (Ali, 2011:179). Passes are either assessed as short passes (Rösch *et al.*, 2000:33) or long passes (Rösch *et al.*, 2000:33; Pedersen *et al.*, 2014:964). This type of assessment method is considered to be subject to the coaches' opinions and the availability of the same coaches over repeated testing sessions (Ali, 2011:179). These types of assessments over short and long distances are also regarded as too simplistic (Ali, 2011:180). It is suggested that the players should rather demonstrate the ability to pass under time constraints and opposing defenders as well as make the decision with regard to whom they should pass, and by this means, be assessed for accuracy and passing under time pressure (Ali, 2011:180).

In addition to technical skills, players also need to possess a sufficient cognitive skill level (Ali, 2011:171) since they are confronted with a complex and rapidly changing environment during a match (Williams, 2000:737). The players need to gather information from the ball, team players and opponents before choosing a suitable response based upon current objectives such as strategy and tactics as well as action constraints such as technical ability and physical capacity (Williams, 2000:737). Proficient skill performance is thus also affected by decision-making (Russell *et al.*, 2011:231). Soccer players, therefore, need to be in possession of diverse technical skills in order to carry out actions such as receiving and controlling a ball, dribbling past an offensive player and shooting in an attempt to score a goal (Ali, 2011:180). The majority of skills performed in a soccer match are open skills, with the exception of certain closed skills such as free kicks and corner kicks (Ali *et al.*, 2007:1470). Even though a vast variety of technical skill-assessment methods exist, a review by Ali (2011) explained that many of these tests have not been validated or tested for reliability; they lack ecological validity and are rather evaluations of the players' 'technique' than evaluations of the players' 'skill'.

Until recently, the lack of a validated soccer passing test has considerably delayed research into soccer skill performance (O'Reilly & Wong, 2012:1035). The recently developed Loughborough Soccer Passing Test (LSPT) now provides an opportunity for researchers to assess the multi-faceted aspects of soccer within a dynamic context that includes passing, dribbling, controlling, shooting and decision-making within match play (Ali *et al.*, 2007:1462). Four wooden rebound boards are placed in a rectangle on four lines, marking a 12.0 m x 9.5 m grid to the inside of the boards (Ali *et al.*, 2008:918). A coloured target area (red, blue, white and green; dimensions: 0.6 m x 0.3 m) is painted or taped in the middle of each wooden board beforehand, and an aluminium strip (0.1 m x 0.15 m) is attached vertically in the middle of each target area (Ali *et al.*, 2008:918). Yellow lines are used to mark the inner (1 m x 2.5 m) and outer (2.5 m x 4.0 m) rectangles to indicate the passing zone, with coloured cones indicating the different zones (Ali *et al.*, 2008:918) (See Figure 1). Players are required to perform 16 passes against the coloured target areas in the fastest possible time, and penalty time for inaccurate passes or poor ball control is imposed (Ali, 2011:180). One examiner calls out the order of passes, based on the coloured target areas and consisting of eight short and eight long passes, while another examiner records the time taken from the start of the test (first pass) to the last completed pass (Ali *et al.*, 2008:918). The ball is played from within the passing area, and penalty time is awarded for the following errors: missing the bench completely or passing to the wrong bench (5 s); missing the target area (3 s); handling the ball (3 s); passing from outside the designated area (2 s); causing the ball to touch a cone (2 s); and exceeding the allocated 43 seconds to complete the test (1 s awarded for each additional second) (Ali *et al.*, 2008:918). However, if the ball hits the aluminium strip, one second is deducted from the total time (Ali *et al.*, 2008:918). The LSPT thus requires players to decide constantly how best to control the ball, how to position themselves for the subsequent pass and how to determine the location of the next target (Ali, 2011:180). Results of the LSPT are typically reported as: time taken to complete the test; penalty time accrued; and total time (Ali *et al.*, 2008:919).

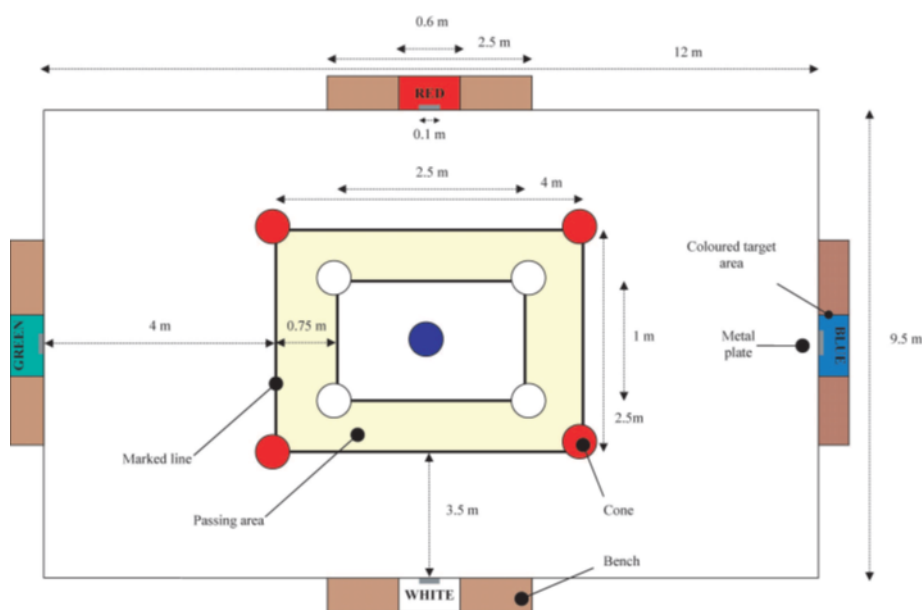


Figure 1: Schematic representation of the Loughborough Soccer Passing Test (Ali *et al.*, 2008) (used by permission)

Ali *et al.* (2008:918) conducted a study on elite and non-elite female soccer players in order to validate the use of the LSPT for female soccer players. The study reported faster times for the elite players compared with the non-elite players regarding time taken to complete the test (54.6 s vs 61.6 s;  $p=0.002$ ), penalty time (22.8 s vs 35.9 s;  $p<0.001$ ) and total overall performance time (77.4 s vs 97.5 s;  $p<0.001$ ) (Ali *et al.*, 2008:919). For the two groups combined, average time taken to complete the test was 57.8 s, penalty time reported was 28.8 s and the average total time was 86.5 s (Ali *et al.*, 2008:919). According to Ali *et al.* (2008:920), there was a good degree of reliability between trial A and trial B (average time:  $r = 0.81$ ; penalty time:  $r = 0.63$ ; total time:  $r = 0.73$ ) for the whole group assessed; however, the elite players produced more consistent results with regard to components measured, took 13% less time to complete the test and accrued 57% less penalty time compared with the non-elite players.

In a different study conducted to examine the validity and reliability of the LSPT, Ali *et al.* (2007:1468) found that first- and second-team (classified as elite) university male players performed better than third- and fourth-team (classified as non-elite) players did. The reported mean times for time taken to complete the test, penalty time and total performance time for the elite players were 40.2 s, 3.3 s and 43.6 s respectively, whereas the mean times reported for the non-elite players were 42.2 s, 10.3 s and 52.5 s respectively (Ali *et al.*, 2007:1466). The elite players completed the test in a faster time ( $p<0.05$ ) than the non-elite players, received a lower penalty time ( $p<0.01$ ) and scored a lower total performance time ( $p<0.01$ ) (Ali *et al.*, 2007:1466).

It is evident that the added penalty time accounts for the largest difference between the elite and non-elite group (Ali *et al.*, 2007:1466). This difference may be the result of better passing accuracy and control of the ball (fine motor skill) by the elite players rather than the speed of completing the test (gross motor skill), although both aspects are regarded as important for skilled soccer movements (Ali *et al.*, 2007:1469). The LSPT can thus distinguish players of different competitive levels in terms of short-passing ability (Ali *et al.*, 2007:1468; Ali *et al.*, 2008:920).

In a further study by Ali *et al.* (2008) among female soccer players, elite players performed the second trial (54.4 s) faster (0.2% difference) than the first trial (54.7 s), while non-elite players performed the first trial (61.2 s) faster (1.3% difference) than the second trial (62.0 s) (Ali *et al.*, 2008:919). In considering the male players in the study of Ali *et al.* (2007:1466), the second trial was performed faster than the first trial by both the elite players (first trial: 40.9 s; second trial: 39.6 s;  $p < 0.01$ ) and non-elite players (first trial: 43.3 s; second trial: 41.0 s;  $p < 0.01$ ). Regarding both female groups in the study of Ali *et al.* (2008:919), more penalty time was accrued during the first trial (elite: 24.7 s; non-elite: 36.0 s) compared with the second trial (elite: 20.9 s; non-elite 35.8 s). This resulted in the elite players producing an overall better performance in the second trial (first trial: 79.3 s; second trial: 75.4 s), and the non-elite players achieving the best overall performance in the first trial (first trial: 97.3 s; second trial: 97.8 s) (Ali *et al.*, 2008:919). Similar tendencies were reported by Ali *et al.* (2007:1466) whereby the male elite and non-elite players accumulated less penalty time in the second trial (elite: 2.7 s; non-elite: 8.6 s) compared with the first trial (elite: 3.9 s; non-elite: 12.0 s), with the results being different ( $p < 0.05$ ) between the two trials for the non-elite players. The total performance time, however, improved for both the elite group (first trial: 44.9 s; second trial: 42.3 s;  $p < 0.05$ ) and non-elite group (first trial: 55.2 s; second trial: 49.9 s;  $p < 0.01$ ) (Ali *et al.*, 2007:1466). The male group in the study of Ali *et al.* (2007:1466) as a whole performed the second trial (40.3 s) faster ( $p < 0.01$ ) than the first trial (42.1 s), accumulated less ( $p < 0.01$ ) penalty time in the second trial (5.6 s) than the first trial (7.9 s) and achieved a better ( $p < 0.01$ ) total performance time in the second trial (46.0 s) compared with the first trial (49.9 s). When the female groups were combined in the study of Ali *et al.* (2008:919), the first trial (57.6 s) was performed faster than the second trial (58.0 s); however, more penalty time was accrued in the first trial compared with the second trial (29.9 s vs 27.7 s), which resulted in a slower overall first trial in comparison with the second trial (87.5 s vs 85.6 s). Ali *et al.* (2007:1469) reported a trial-order effect in which performance showed improvement from the first to the second trial and explained that more attempts to familiarise the players with the test would reduce this learning effect. Ali *et al.* (2008:920) also recommended that players attend at least one familiarisation session, preferably two.

In summary, the LSPT has the ability to distinguish various components of skill performance between grades (Ali *et al.*, 2008:921). The LSPT includes a dynamic element in which the player needs to respond to the investigator's call, needs to make use of memory and perception to identify the next pass in the sequence and needs to perform the motor tasks of controlling, dribbling and passing against a specific target (Ali & Williams, 2009:1500). The study by Ali *et al.* (2008:920) confirmed that the LSPT is a valid and reliable method for examining soccer skill performance in female soccer players. However, the authors recommend that future studies utilising the LSPT should focus on the highest level of soccer players at their disposal because their study found more consistent performance among the elite players due to lower random error (Ali *et al.*, 2008:920). The study conducted on male players also reported a higher repeatability of the LSPT for elite players and specified that the most reliable aspect of the test was the time taken to complete the test since it had the lowest standard error of measurement (Ali *et al.*, 2007:1466). The test was also found to be more reliable among the elite male players when compared with the non-elite players (Ali *et al.*, 2007:1469). Players of a higher skill level were able to perform the test faster without compromising their ability to make accurate passes and control the ball (Ali *et al.*, 2007:1470).

#### **2.4.2 Effects of aerobic fatigue on technical skill performance**

A vital component of a sport in which the aim is to score more goals than the opponent is the ability to maintain good technical performance throughout the exercise (Russell *et al.*, 2010:1399). However, the physiology of intermittent exercise, the technical responses such as skill performance that includes passing, shooting and dribbling and the physical demands of team sports are not well understood (Russell & Kingsley, 2011:524). In addition, limited information exists regarding the effects of fatigue on the performance of soccer skills (Ali & Williams, 2009:1499). Due to the fact that many sport skills are performed in a fatigued state, there is a need to assess skill acquisition and performance in this condition (Lyons *et al.*, 2006:200). According to Lyons *et al.* (2006:197), soccer players are likely to suffer temporarily from fatigue, specifically towards the end of a match. It has also been proved that the critical period for scoring and conceding goals is between the 76<sup>th</sup> and 90<sup>th</sup> minute of the match (Njororai, 2014:62). Furthermore, Njororai (2014:61) claimed that players who are tired are prone to errors in judgement in terms of the timing of passes, marking, meeting crosses, timing of tackles, passing back to the goalkeeper and defensive clearance. Rampinini *et al.* (2008:939) suggested that the decrement in short-passing ability during a match is very similar to that found for physical performance.

Studies by Rampinini *et al.* (2008), Mujika *et al.* (2009), and Stone and Oliver (2009) focused on the impact of fitness level on soccer skill performance. The study by Stone and Oliver (2009:164) on male soccer players assessed the effect of a 45-minute Loughborough Intermittent Shuttle Test (LIST) on the ability to dribble a ball (measured through a slalom dribbling test). The dribbling test was initially performed in isolation and was followed by the LIST on a subsequent day (Stone & Oliver, 2009:165). The slalom dribbling time increased by 4.5% (ranging between 1.5% and 11.4%) ( $p < 0.05$ ) after implementation of the 45-minute LIST (Stone & Oliver, 2009:169). This increase in dribbling time supports the notion that fatigue results in a reduced speed of skill execution, which is attributed to reduced motor control when in control of the ball (Stone & Oliver, 2009:173).

Short-passing ability measured through the modified version of the LSPT (mLSPT) was influenced negatively when total performance time was measured from pre-match (65.5 s) to after the first half (75.3 s) and the second half (78.1 s) of the match ( $p < 0.001$ ) (Rampinini *et al.*, 2008:937). Passing precision calculated by means of penalties decreased ( $p < 0.001$ ) from the start (16.9 s) to the end of the first half (24.1 s; 43.0%) and the second half (27.3 s; 62%) of the match (Rampinini *et al.*, 2008:937). The time taken to complete the mLSPT also increased by 4.0% and 5.0% after the first half and the second half of the match respectively, suggesting a decrease in dribbling performance (Rampinini *et al.*, 2008:937). Assessments conducted at different time intervals throughout the match indicated that penalty time (accrued due to number of mistakes made during performance of the mLSPT) increased by 17% during the first half, increased by 41% after the first half and during the second half and increased by as much as 60% after the second half ( $p < 0.01$ ) (Rampinini *et al.*, 2008:937). This resulted in a total performance time for the mLSPT deteriorating by 13% after the first half and 18% after the second half (Rampinini *et al.*, 2008:938). In conclusion, match-related fatigue has a detrimental effect on short-passing ability (Rampinini *et al.*, 2008:940). The mLSPT time is influenced by the player's ability to control the ball as well as time lost to bring the ball under control due to imprecise passes (Rampinini *et al.*, 2008:940). Since the accuracy of passes performed decreased by 40–60%, it is likely that physical fatigue influences passing accuracy more than dribbling ability (Rampinini *et al.*, 2008:940).

A different study protocol used by Impellizzeri *et al.* (2008:1193) investigated the effect of aerobic training on the decline in short-passing ability induced by a five-minute simulation. Impellizzeri *et al.* (2008:1196) claimed that although physical training permits fitter players to perform more physical activities during games, a reduction in short-passing ability similar to that in less fit players is still experienced. Following an eight-week, HI aerobic training intervention, it was

reported that junior male elite players performed more successful passes during matches from pre-training (19.4) to post-training (23.5) and less unsuccessful passes during matches from pre-training (9.1) to post-training (7.2) (Helgerud *et al.*, 2001:1928). Impellizzeri *et al.* (2008:1196) further reported that exercise-induced fatigue influences passing accuracy more than it influences the ability to control and move with the ball. The study found that the enhancement of aerobic power and soccer-specific endurance can decrease the deterioration in technical skill proficiency due to fatigue (Impellizzeri *et al.*, 2008:1196).

A soccer-skill test battery making use of video analysis was used to assess passing, shooting, dribbling and decision-making (Russell *et al.*, 2010:1400; Russell *et al.*, 2011:223). Attempts were also made to determine if 90 minutes of soccer-specific exercise would have an influence on the quality of skill performance when assessed using the particular test battery (Russell *et al.*, 2011:222). Russell *et al.* (2011:223) used a protocol consisting of 90 minutes of intermittent activity that was completed in two 45-minute halves and separated by a 15-minute recovery period (regarded as half time). The exercise periods were divided into 4.5-minute blocks, consisting of different types of intermittent exercise (Russell *et al.*, 2011:224). Seven of these block exercises (followed by skill testing) were completed during each half, resulting in a total distance of 10.1 km being covered by players with 56 passes, 16 shots at target and 21 dribbles (Russell *et al.*, 2011:224). Shooting accuracy declined by 25% from before exercise to after exercise, while passing success and dribbling precision remained similar throughout the exercise period (Russell *et al.*, 2011:227, 228, 230). The protocol allowed for the assessment of ball speed during skill execution and found that shots performed in the second half of the exercise were slower than shots performed in the first half and that passing speed was reduced ( $p=0.011$ ) over the 90 minutes (Russell *et al.*, 2011:227, 228). Dribbling success and ball speed were similar between halves (Russell *et al.*, 2011:230). The study concluded that passing and shooting performance declined as a result of fatigue caused by simulated match play (Russell *et al.*, 2011:230).

Stone and Oliver (2009:164) used a different method to assess the effect of a 45-minute LIST on the ability of male players to shoot at the goal area, which was measured through the Loughborough Soccer Shooting Test (LSST). The study reported a reduction in points scored in the LSST (-7.6;  $p=0.012$ ) after the implementation of the LIST, with some players showing a change in score of more than 25% (Stone & Oliver, 2009:169). A further reduction of 47% in the number of shots achieving the maximum of five points and an 85% increase in the number of shots achieving the minimum of zero points, were also recorded (Stone & Oliver, 2009:169). It was added that players may sacrifice speed of movement to maintain accuracy when in a fatigued state; however, players were unable to sacrifice speed during the LSST due to the time limits

imposed and as a result, accuracy declined (Stone & Oliver, 2009:173). It is evident through the changes in the distribution of points scored that shooting accuracy is reduced when players are fatigued, which would have obvious consequences in regard to the match outcome (Stone & Oliver, 2009:173).

Two studies focused on the influence of prolonged intermittent exercise (measured through the LIST) on the soccer skill performance (measured through the LSPT) of sub-elite male soccer players (Ali *et al.*, 2007:1970; Ali & Williams, 2009:1500). Regarding the study of Ali *et al.* (2007:1971), the results reported for the LSPT total performance time pre-LIST and post-LIST were 51.2 s and 54.0 s respectively. A tendency was noticed for the group to accrue more penalty time post-LIST than pre-LIST (11.5 s to 9.1 s) (Ali *et al.*, 2007:1972). This increase in penalty time suggests a deterioration in fine motor control (passing and ball control) and/or cognitive functioning (decision-making and perceptual awareness) (Ali *et al.*, 2007:1974). Ali and Williams (2009:1501) also utilised a 90-minute LIST but conducted the LSPT at 15-minute intervals. The results indicated that penalty time increased towards the end of the exercise (Ali & Williams, 2009:1502). A 14% reduction in performance was observed (Ali & Williams, 2009:1505). Total performance time deteriorated mostly at 75 minutes (45 s) of exercise and at 90 minutes (44 s) of exercise (Ali & Williams, 2009:1503).

The distance covered by male soccer players in a 45-minute LIST was 6 000 m, which was suggested to be comparable with distances covered in the first half of a soccer match (Stone & Oliver, 2009:171). Consequently, it was explained that skill was reduced following 45 minutes of exercise, which explains the deterioration of skill by the end of the first half of a soccer match (Stone & Oliver, 2009:171). In addition, the decline in soccer skill performance during the last 15 minutes of exercise in a 90-minute intermittent running test reported by Ali and Williams (2009:1507) supports the notion that the most goals in a match are scored during this period for various reasons such as changes in arousal level that lead to lapses in concentration or ball control by players towards the end of a match. It is thus evident that superior technical ability can only be consistently demonstrated throughout a 90-minute match by players who possess a high level of endurance capacity (Stølen *et al.*, 2005:503).

The players' aerobic capacity plays a major part in modern soccer and can influence technical performance considerably (Chamari *et al.*, 2005:24). It was further suggested that players with a higher level of aerobic fitness play at a higher tempo, possibly creating more scoring opportunities than players with a lower level of aerobic fitness (Aziz *et al.*, 2007:10). When viewed in terms of league positional ranking, it could thus be postulated that the clubs consisting of players who

possess a higher fitness level would score more and/or concede less goals, winning a greater number of matches (Aziz *et al.*, 2007:11). Endurance training in soccer should ideally be conducted using a soccer ball, and players may then additionally develop technical and tactical skills similar to situations experienced during the match (Helgerud *et al.*, 2001:1930).

### 2.4.3 Effects of anaerobic fatigue on technical skill performance

Soccer performance is greatly influenced by anaerobic actions such as those involved in the execution of technical skills (Russell *et al.*, 2011:511). The contribution of anaerobic metabolism to energy provision is essential during a soccer match as skilful actions are dependent on quick and powerful movements (Ali & Williams, 2009:1500). It is, however, unclear to what extent intense exercise affects a player's technical skills (Rostgaard *et al.*, 2008:283). Both sprinting and jumping are involved in ball possession and repossession, defence play, corner kicks and goal attacks (Haugen *et al.*, 2012:340). It is evident that soccer performance at a high level is characterised by a significant amount of HI exercise performed during a match (Rostgaard *et al.*, 2008:283). Russell *et al.* (2010:1399) claim that soccer requires the concurrent performance of technical skills throughout HI intermittent exercise. According to Njororai (2014:61), the exertions while chasing to regain ball possession can be physically draining if a team resorts to launching an attack immediately after acquiring possession.

A study investigating the effects of moderate- and high-intensity localised muscle fatigue (fatiguing of the quadriceps and hamstring muscle groups) on the performance of a mLSPT conducted by Lyons *et al.* (2006:200) found that HI localised muscle fatigue had a detrimental effect on certain components of the mLSPT such as performance scores, passing errors and total errors. Lyons *et al.* (2006:201) proposed that the results obtained suggest that the decreased performance of the mLSPT could be a direct or indirect result of the inability of the specific muscle groups to cope with the demands of the task in terms of speed and/or accuracy. Players produced their best performance in the mLSPT at 70% of maximal fatigue and their worst performance at 90% of maximal fatigue, with the least number of passing penalties accrued at 70% and most penalties accrued at 90% (Lyons *et al.*, 2006:199). The study consequently proved that fatigue at 90% has a detrimental effect on passing accuracy and total performance scores (Lyons *et al.*, 2006:200).

Another study conducted on junior male professional soccer players claimed that the diminished performance in executing the mLSPT induced by the completion of short bouts of HI activities is correlated to the physical fitness of the player (Rampinini *et al.*, 2008:939). The study made use of a HI simulation to determine the effect of high-intensity activity HIA on the short-passing ability

of players when measured through the mLSPT (Rampinini *et al.*, 2008:936). The main findings included a decrease in passing accuracy after the HI simulation, as measured through the increase ( $p < 0.05$ ) in penalty time accumulated, thus indicating that fatigue as a result of HIA of short duration could result in a deterioration of short-passing skills (Rampinini *et al.*, 2008:938,939).

A different study conducted by Rostgaard *et al.* (2008:283) examined the effect of intense soccer activities on the technical performance of male soccer players. The test battery consisted of HIR and dribbling actions alternated by active recovery as well as 10 long passes towards a “goal zone” (Rostgaard *et al.*, 2008:285). The findings showed that the kicking performance from the last five kicks was reduced compared with the first five kicks, suggesting that the particular physical activity influenced the players’ kicking ability (Rostgaard *et al.*, 2008:289). Also, a difference ( $p < 0.05$ ) was found in the performance of youth elite and sub-elite players, with the best performances being observed among the youth elite players (Rostgaard *et al.*, 2008:289). This was not surprising since the youth elite players engaged in more training sessions per week (Rostgaard *et al.*, 2008:284).

Elite soccer players need to possess a large range of motor skills in addition to the ability to process information and make decisions rapidly because play alternates between attacking and defending activities (Wallace & Norton, 2014:223). These physical and motor attributes occur within a tactical framework consisting of set plays and different playing styles and team strategies, which may require adaptations depending on the opposition, environmental conditions and score line (Wallace & Norton, 2014:223). Stone and Oliver (2009:172) suggest that technical training should be conducted under conditions of fatigue to ensure players can maintain skill execution when fatigued. It is also suggested that players may differ physiologically in their ability to tolerate fatigue; some players’ performance is not impaired with regard to speed or accuracy, some players’ performance is impaired with regard to speed or accuracy and other players experience impairment in both speed and accuracy (Stone & Oliver, 2009:173). As indicated by Rampinini *et al.* (2008:941), the decline in performance in a technical skill-assessment battery as a result of match-related fatigue is indirectly associated with the physical fitness level of the player. Thus, the higher the fitness level, the lower is the physical fatigue experienced by the player, ultimately resulting in less deterioration in technical proficiency (Rampinini *et al.*, 2008:941).

Dribbling is more resilient than other technical skills to the effects of match-related fatigue (Russell *et al.*, 2011:231). It is, however, clear that physical stress experienced during a match can influence the technical performance of soccer players (Rostgaard *et al.*, 2008:291). Thus, the

challenge confronting coaches is to develop the team all round in terms of physical capacity, technique, tactics and mental concentration in order for players to endure the various situations encountered during a match (Njororai, 2014:62). The development of more sensitive and ecologically valid outcome measures for determining the effect of fatigue on technical performance will also lessen the degree of disagreement among researchers (Russell *et al.*, 2011:231).

## **2.5 External and internal match demands placed on female soccer players**

The successful evaluation of the physical demands on players requires the accurate assessment of both external and internal demands (Gaudino *et al.*, 2015:860).

### **2.5.1 Quantifying external movement demands by means of global positioning system technology**

It is especially important to understand the energy demands of sports and their specific positions in order to develop optimal training drills and match simulations (Edgecomb & Norton, 2006:25). Several methods have previously been used to determine the movement demands during soccer matches and consist mainly of semi-automated video systems such as ProZone and AMISCO (Mohr *et al.*, 2003; Burgess *et al.*, 2006; Di Salvo *et al.*, 2010; Randers *et al.*, 2010) and global positioning system (GPS) analysis (Edgecomb & Norton, 2006; Casamichana & Castellano, 2010; Molinos Domene, 2013; Randers *et al.*, 2010). Unfortunately, certain limitations exist with regard to the use of semi-automated video tracking systems such as not being able to function in real time, being subject to possible errors due to gait changes during movements performed and being extremely labour-intensive since direct observation of players is required by trained specialists (Edgecomb & Norton, 2006:26). The cameras also need to be installed at the top of a stadium, restricting assessments of matches played at that particular stadium (Di Salvo *et al.*, 2010:1490).

A valuable tool for enhancing physical-activity assessment utilises GPS technology (Maddison & Ni Mhurchu, 2009:73). The use of GPS devices allows a more comprehensive study of locomotion patterns in soccer since GPS devices have greater objectivity and higher time-resolution, which is more beneficial in comparison with the time-consuming video-based time-motion analysis (TMA) (Randers *et al.*, 2010:172). Global positioning systems also allow for real-time data evaluation (Edgecomb & Norton, 2006:26; Aughey & Falloon, 2010:348). This technology provides quantitative information pertaining to the position, displacement, velocity and acceleration of players (Dwyer & Gabbett, 2012:818). The position of a GPS device is determined through measuring the distance between the device and three or more GPS satellites, which is

achieved by constantly receiving and analysing radio signals from the satellites and calculating the precise distance to each satellite (Maddison & Ni Mhurchu, 2009:73). Once the location is known, displacement over a specified period can be used to calculate velocity of movement (Aughey, 2011:296). However, the GPS device can only be used on outdoor fields (Aughey, 2011:306), and the signal is affected by environmental conditions such as heavy tree cover, dense urban areas or the device being inside a building (Maddison & Ni Mhurchu, 2009:73). These devices are suitable for many team sports since they are small, lightweight and can store a few hours of data (Aughey, 2011:300). Another benefit of GPS technology is its reasonable cost and its portability, which allows for easy data collection in any competition venue (Schutz & Chambaz, 1997:339; Aughey, 2011:303). Aughey (2011:303) describes this as a major advantage when compared with sports where the norm is to fit stadiums rather than the players with instrumentation. The use of GPS devices and semi-automated camera systems is now relatively commonplace in men's soccer (Datson *et al.*, 2014:1226).

However, Datson *et al.* (2014:1226) acknowledged that despite advancements in the understanding of match play of male players, published research on elite female players is lacking. The first study to describe the sprint profile of professional female soccer players during matches was conducted by Vescovi (2012a). Datson *et al.* (2014:1226) attributes this to stadium access and financial considerations. This makes it particularly difficult to make comparisons and, therefore, the researcher makes use of trends found in male soccer as well as TMA studies on female players as part of this discussion.

### **2.5.1.1 Validity and reliability of GPS devices for use in soccer**

Coutts and Duffield (2010:134) reported a good accuracy level (coefficient of variation (CV) <5%) for the actual measured distance using GPS devices sampling at 1 Hz. The study also made reference to the fact that newer GPS devices sampling at a greater frequency in general appear to be more accurate and reliable than older devices (Coutts & Duffield, 2010:135). Another study examined the validity and reliability of GPS units, sampling at 1 Hz and 5 Hz in order to establish which is more valid and reliable during linear, multidirectional and soccer-specific movement (Portas *et al.*, 2010:449). For multidirectional movement, both 1 Hz and 5 Hz devices were found to be valid (standard error of the estimate (SEE) 1.8–4.2% and 2.2–4.4% respectively), except for 180° turns using 1 Hz devices (SEE 3.0–6.8%) (Portas *et al.*, 2010:453). Reliability of the linear and soccer-specific movements was also within 5% for both the 1 Hz and 5 Hz devices (Portas *et al.*, 2010:455). It was further noted that sampling with GPS devices at 1 Hz may not be sufficient in detecting important changes in running distance at speeds of greater than 20 km/h (Coutts &

Duffield, 2010:135) and that reliability decreases with increasing course complexity (Portas *et al.*, 2010:456). Portas *et al.* (2010:455) recognised a limitation in the use of a GPS device in that the device underestimates distance in confined spaces although a 5 Hz device is more accurate at higher speed than a 1 Hz device in small spaces. They also suggested that the results from different GPS devices should not be used interchangeably in the analysis of HIR due to differences in reported distance measurements when using devices that are sampling at different frequencies (Coutts & Duffield, 2010:135).

Direct comparison across studies is difficult if the aim is a general statement on the validity and reliability of using GPS devices in team sports due to the variety of exercise tasks, GPS devices, sampling rates and statistical methods used (Aughey, 2011:297). Recent advancements in this technology have led to the increase in the sampling rate of GPS devices from 5 Hz to 10 Hz and 15 Hz (Johnston *et al.*, 2014:1650). Sampling by GPS devices at a higher rate seems to be more valid in measuring HIR distance (Aughey, 2011:297). A recent study proved that a 10 Hz GPS is two to three times more accurate than a 5 Hz GPS and up to six times more reliable (Varley *et al.*, 2012:125). The 10 Hz GPS can also accurately determine whether an acceleration or deceleration has occurred (Varley *et al.*, 2012:125). Unlike GPS devices that sample at a slower rate, the 10 Hz GPS is able to detect the smallest worthwhile change in performance relating to constant velocity, acceleration and deceleration (Varley *et al.*, 2012:123).

It is also suggested that the longer the duration of the task being measured, the more valid the GPS measured distance becomes (Aughey, 2011:299). However, in a comparison with 10 Hz devices, sampling by GPS devices at a greater rate such as 15 Hz was found to display lower levels of inter-unit reliability for all movement demands assessed in a study by Johnston *et al.* (2014:1653). Thus, not only do the 10 Hz devices demonstrate an improved ability to measure team sport movement demands when compared with the 1 Hz and 5 Hz devices, but they also prove to be more valid and reliable than the 15 Hz devices (Johnston *et al.*, 2014:1654). Global positioning system technology is, therefore, labelled as valid and reliable enough for detecting altered running movements across a match and between matches, as well as between different competition levels (Aughey, 2011:303).

### **2.5.1.2 Categorisation of locomotor activities in soccer match play**

In soccer, movement activities are generally classified according to intensity, which is determined by the speed of the action (Carling *et al.*, 2008:852). The main categories used to analyse work rate are standing, walking, jogging, cruising (striding) and sprinting (Carling *et al.*, 2008:852). Sprinting is regarded as the highest intensity effort performed during a match (Vescovi,

2012a:1259). Activities classified as low-intensity (LI) such as walking and jogging tend to be more dominant in soccer (Carling *et al.*, 2008:852), while the distance covered at HIR is considered an important indicator of match performance (Mohr *et al.*, 2003:527). Vescovi (2012a:1259) claims that the quantification of this measure requires consistent implementation of speed thresholds that accurately reflect the ability of the players.

In the study of Randers *et al.* (2010:173), various movement categories for male soccer players were used in order to compare the different match-analysis systems of video-based TMA, a semi-automated camera system and two GPS devices sampling at 1 Hz and 5 Hz. The movement categories were standing (0–2 km/h), walking (2–7 km/h), jogging (7–9 km/h), low-speed running (9–13 km/h), moderate-speed running (13–16 km/h), high-speed running (16–22 km/h) and sprinting (>22 km/h) (Randers *et al.*, 2010:173). Using a pre-designed team-sport running circuit, Coutts and Duffield (2010:134) made use of three movement categories: low-intensity activity (LIA) (<14.4 km/h), HIR (>14.4 km/h) and increased HIR (>20 km/h). The AMISCO Pro camera system was utilised by Di Salvo *et al.* (2007:223), and movement intensity was divided into the categories of: standing, walking and jogging (1–11 km/h); low-speed running (11.1–14 km/h); moderate-speed running (14.1–19 km/h); high-speed running (19.1–23 km/h); and sprinting (>23 km/h). A more recent study that made use of GPS devices sampling at 10 Hz applied different movement categories than those previously employed, and these included stationary-walking (0–3.9 km/h), jogging (4–6.9 km/h), quick running (7–12.9 km/h), HIR (13–17.9 km/h) and sprinting (>18 km/h) (Molinos Domene, 2013:1019).

In elite female soccer matches, Krusturp *et al.* (2005:1243) and Mohr *et al.* (2008:342) employed video-based TMA and used somewhat different classifications than those applied in matches of male players, and these consisted of standing (0 km/h), walking (6 km/h), jogging (8 km/h), low-speed running (12 km/h), moderate-speed running (15 km/h), high-speed running (18 km/h), sprinting (25 km/h) and backward running (10 km/h). These classifications were later divided into four locomotor categories: standing, walking, low-intensity running (LIR) (consisting of jogging, low-speed running and backward running) and HIR (consisting of moderate-speed running, high-speed running and sprinting) (Krusturp *et al.*, 2005:1243; Mohr *et al.*, 2008:342). A different approach by Bradley *et al.* (2014:161) did not categorise movement into speed categories such as jogging, running or sprinting but made reference to the different speed zones of 0–12 km/hr, 12–15 km/hr, 15–18 km/hr, 18–21 km/hr, 21–23 km/hr, 23–25 km/hr and 25–27 km/h. Through the use of a multi-camera system, this study focused on gender differences with regard to time spent in different speed zones during matches and explained that movement was not classified into different categories since peak-speed characteristics and anaerobic-threshold indices of

female players are substantially lower than their male counterparts (Bradley *et al.*, 2014:161). Using 5 Hz GPS devices, movement categories of standing (0–0.4 km/h), walking (0.5–6 km/h), jogging (6–12 km/h), running (12–19 km/h) and sprinting (>19 km/h) were incorporated in 13 international female matches through the assessment of 15 Australian female national team players, resulting in a total of 58 game files (Hewitt *et al.*, 2014:1875).

Somewhat similar classifications were used by Barbero Álvarez *et al.* (2008:3) in measurements with 1 Hz GPS devices (Table 4). However, this study assessed young female players, using lower movement categories due to differences in age, training hours, physical condition, competitive experience, game time and competitive level (Barbero Álvarez *et al.*, 2008:7). The movement categories of strolling (0–5 km/h), walking (5–8 km/h), low-speed running (8–12 km/h), moderate-speed running (12–16 km/h), high-speed running (16–20 km/h) and sprinting (>20 km/h) that were reported in a study of national-level female players employing GPS devices (Hewitt *et al.*, 2009:225), used classifications comparable with the low movement categories of previous studies that employed video analysis (Krustrup *et al.*, 2005:1243; Mohr *et al.*, 2008:342; Andersson *et al.*, 2010b:914).

**Table 4: Movement threshold (km/h) categories for female and male soccer players**

Author	Assessment method	Standing	Walking	Jogging	Low-speed running	Moderate-speed running	High-speed running	Sprinting
Female players								
Hewitt <i>et al.</i> (2014:1875)	5 Hz GPS	0–0.4	0.5–6	6–12		12–19		>19
Vescovi and Favero (2014:406)	5 Hz GPS		0–6	6.1–8	8.1–12	12.1–15.5	15.6–20	>20
Andersson <i>et al.</i> (2010b:914)	Video	0	6	8	12	15	18	25
Hewitt <i>et al.</i> (2009:225)	GPS	0–5 (strolling)	5–8		8–12	12–16	16–20	>20
Barbero Álvarez <i>et al.</i> (2008:3)	1 Hz GPS	0–0.4	0.5–3		3.1–8	8.1–13	13.1–18	>18.1
Mohr <i>et al.</i> (2008:342)	Video	0	6	8	12	15	18	25
Krustrup <i>et al.</i> (2005:1243)	Video	0	6	8	12	15	18	25
Male players								
Molinos Domene (2013:1019)	10 Hz GPS	0–3.9		4–6.9		7–12.9 (quick running)	13–17.9	>18
Coutts and Duffield (2010:134)	1 Hz GPS				<14.4 (LIA)		>14.4 (HIR)	>20 (increased HIR)
Randers <i>et al.</i> (2010:173)	Video; semi-automated camera; GPS	0–2	2–7	7–9	9–13	13–16	16–22	>22
Vigne <i>et al.</i> (2010:305)	SICS multi-cameras		<5	5–13		13–16 (below anaerobic threshold)	16–19 (above anaerobic threshold)	>19
Di Salvo <i>et al.</i> (2007:223)	AMISCO Pro multiple cameras		0–11		11.1–14	14.1–19	19.1–23	>23

Abbreviations: GPS: Global Positioning System; HIR: High-intensity running; LIA: Low-intensity activity

Other studies also made reference to speed intensity by categorising the movements into metres per second (m/s) (Roberts *et al.*, 2006:391; Dwyer & Gabbett, 2012:820; Varley *et al.*, 2014:1860). Roberts *et al.* (2006:391) utilised video cameras and divided the speed intensities into six velocity bands that consisted of standing or non-purposeful movement (0–0.5 m/s), walking (0.5–1.7 m/s), jogging (1.7–3.6 m/s), medium-intensity running (3.6–5 m/s), HIR (5–6.7 m/s) and maximal speed running (>6.7 m/s). Varley *et al.* (2014:1860) employed 5 Hz GPS devices with velocity-band classifications of LIA (0–5.4 m/s), high-velocity running (>5.5–10 m/s) and sprinting (>7–10 m/s).

Alternatively, Dwyer and Gabbett (2012:820) made use of 1 Hz GPS devices and five velocity bands for female soccer, namely standing (0.0–0.1 m/s), walking (0.2–1.6 m/s), jogging (1.7–3.3 m/s), running (3.4–5.3 m/s) and sprinting (5.4 m/s). Locomotor activities also defined for female soccer players include: standing and walking (0.0–1.6 m/s), jogging (1.7–2.2 m/s), low-intensity running (2.3–3.3 m/s), moderate-intensity running (3.4–4.3 m/s), high-intensity running (4.4–5.6 m/s) and sprinting (>5.6 m/s) (Vescovi, 2014:111; Vescovi & Favero, 2014:406). According to Bradley and Vescovi (2015:112), no methodological standardisation of velocity threshold currently exists to quantify accurately locomotor activities during female matches, making it difficult to compare studies and develop cohesive views about locomotor characteristics of female soccer. However, based on a review of different studies, Bradley and Vescovi (2015:114) suggest velocity thresholds of 15 km/h to 16 km/h for high-speed running and 20 km/h for sprinting in female soccer.

### **2.5.1.3 Motion analysis of female soccer matches**

A review published by Martínez-Lagunas *et al.* (2014:265) focused on the physical demands encountered by female players during games and from a large range of studies, summarised that the mean values for total distance covered (4–13 km) and distance covered at different speeds vary according to the players' nationality, competitive level and position, as well as according to the measuring method used within the study. A study conducted by Krusturp *et al.* (2005:1244) assessed the activity patterns of elite female Danish players during a 90-minute match using TMA and found that the players covered a total distance of 10.3 km during the match. Similar distances were published for the United States (US) national team players (10.3 km) and elite Danish and Swedish players (10.4 km) (Mohr *et al.*, 2008:344). Another study that used TMA reported total distances of 9.9 km and 9.7 km for elite female players who participated in international matches and the domestic league respectively (Andersson *et al.*, 2010b:914). Global positioning system analysis also revealed distances of 9.1 km (Hewitt *et al.*, 2009:226), 9.6 km (Hewitt *et al.*, 2014:1876), 10.1 km (Vescovi, 2015) and 10 km (Mara *et al.*, 2016) for female players. A recent study on sub-elite female players reported an average of 5.5 km, although this was based on the playing time of all the players, including the substituted players (Gentles *et al.*, 2018:6). The study reported a range of 1.1-13.9 km for total distance covered (Gentles *et al.*, 2018:6).

An evaluation of the demands of different playing positions is vital to ensure specificity of training of players; however, there is also a shortage of information in this area (Datson *et al.*, 2014:1226). Results of Gabbett and Mulvey (2008:546) regarding elite female soccer players indicated that the greatest total distance was covered by midfielders (10.6 km), followed by defenders (9.6 km)

and forwards (9.6 km). In a different study, female midfielders participating on an international level also covered a greater ( $p < 0.05$ ) distance (10.6 km) in comparison with defenders (9.5 km) (Andersson *et al.*, 2010b:916). A difference ( $p = 0.001$ ) in distance covered was also found in more recent studies by Hewitt *et al.* (2014:1877) and Mara *et al.* (2016) between midfielders (10.1-10.6 km) and defenders (8.7-9.2 km). Forward players covered a total of 9.8 km (Andersson *et al.*, 2010b:918; Ramos *et al.*, 2017) and 9.4 km (Hewitt *et al.*, 2014:1877) in three respective studies. The distances reported for the female midfielders in international matches were also higher ( $p < 0.05$ ) in comparison with the defenders (9.5 km), the midfielders (10.1 km) and the forwards (9.5 km) of domestic league matches (Andersson *et al.*, 2010b:916). Similar results were found by Hewitt *et al.* (2009:226) in that midfielders covered more distance (9.6 km) during international matches in comparison with defenders (9.0 km) and attackers (8.5 km). The differences reported for distance covered during matches may be due to different playing styles, differences in methods of analysis, styles of play of opposition players and the players' physical capacities (Hewitt *et al.*, 2009:226). Despite these differences, a high level of aerobic endurance is required by female players due to the characteristics and demands of soccer matches (Milanovic *et al.*, 2012:68).

A number of studies reported on the time that female soccer players spent in different movement categories or speed zones, which were identified by means of video analysis (Gabbett & Mulvey, 2008; Mohr *et al.*, 2008; Andersson *et al.*, 2010b) or GPS analysis (Hewitt *et al.*, 2009; Vescovi, 2012a; Hewitt *et al.*, 2014; Vescovi & Favero, 2014; Nakamura *et al.*, 2016). However, comparisons between studies are difficult due to different assessment methods, movement categories and levels of participation. During a 90-minute match, Krstrup *et al.* (2005:1244) noted a total number of 1 459 activity changes, which corresponded to an activity change every four seconds. A total number of 1 379 and 1 326 activity changes have also been reported for professional and top-level female players respectively (Mohr *et al.*, 2008:344). In another study that tracked the same players in domestic and international matches, the number of activity changes (1 593 vs 1 641) was reported to be the same, regardless of the level of participation (Andersson *et al.*, 2010b:915).

In terms of different movement categories, Krstrup *et al.* (2005:1244) indicated through video analysis that female players completed 9 km at LIR. Players spent 16% of the total time standing, 44% walking and 34% running at LI (Krstrup *et al.*, 2005:1244). An analysis of the movements performed by national-level female players showed that the players spent 19% of the total time standing, 42% walking and 27% performing LIR (Mohr *et al.*, 2008:345). In agreement with these results, Gabbett and Mulvey (2008:547) noted that players in elite female matches spent 15% of

the total time standing, 50% walking and 26% jogging. These results confirm that the majority of the time in soccer match play is spent in LIA (Gabbett & Mulvey, 2008:550). Using GPS analysis, percentage values of 30% walking, 12% jogging and 32% LIR have also been reported for sub-elite female players (Vescovi & Favero, 2014:408). Female Australian national team players at elite level spent 26% of the total time (2 400 m) at slow-paced walking, 23% (2 100 m) walking, 26% (2 330 m) low-speed running and 15% (1 410 m) moderate-speed running (Hewitt *et al.*, 2009:226). Video analysis of different playing positions revealed that in international competitions, forwards covered more distance in terms of walking compared with midfielders and defenders (3 432 m, 35% vs 3 104 m, 29% vs 3 104 m, 32%) (Gabbett & Mulvey, 2008:546). Again, midfielders covered a further distance by jogging (4 646 m, 43%) than defenders (4 366 m, 45%) and forwards (3 813 m, 39%) (Gabbett & Mulvey, 2008:546). When measured in terms of time spent in LI movement categories, forwards spent 16%, 52% and 23% standing, walking and jogging respectively, while midfielders spent 14%, 49% and 27% and defenders spent 16%, 49% and 27% in these three specific movement categories (Gabbett & Mulvey, 2008:546).

Vescovi and Favero (2014:407) compared the first- and second-half match performance of players in different positions and made use of GPS devices, sampling at 5 Hz for the analysis. Forwards covered the least distance by means of walking during the first and the second half (1 482 m and 1 540 m) in comparison with the midfielders (1 516 m and 1 647 m) and the defenders (1 540 m and 1 586 m) (Vescovi & Favero, 2014:407). Results show that the defenders covered less distance jogging (607 m and 567 m) during both halves than the forwards (667 m and 570 m), and the midfielders (677 m and 639 m) covered the furthest distance among the three groups (Vescovi & Favero, 2014:407). The defenders also covered less ( $p < 0.05$ ) distance than the midfielders in terms of LIR during the first half (1 442 m vs 1 675 m), while the forwards completed 1 655 m at LIR (Vescovi & Favero, 2014:407). Distances of 1 483 m, 1 446 m and 1 292 m were reported for LIR during the second half for forwards, midfielders and defenders respectively (Vescovi & Favero, 2014:407).

Since a large proportion of female matches consists of LI movement such as walking and jogging, it is important to identify the patterns of HIA during matches (Hewitt *et al.*, 2014:1874). The study by Krusturp *et al.* (2005:1244) revealed a total of 125 HI runs performed with an average duration of 2.3 s and a total number of 26 sprints, accounting for 4% of the total match time. This amounted to a total of 1.3 km performed at HIR and 0.2 km sprinting (Krusturp *et al.*, 2005:1244). Further HIR and sprinting distances of 2 407 m and 338 m respectively were reported in a more recent study (Hewitt *et al.*, 2014:1876). Shorter distances of 620 m (7%) and 280 m (3%) were reported in another study for HIR and sprinting respectively (Hewitt *et al.*, 2009:226). An average of 18

sprints with a mean duration of 2.5 s and total sprint distance of 285 m have also been reported recently (Nakamura *et al.*, 2016). These variances reported in results may be due to differences in competitive levels (league team vs national team), measurement methods used (video analysis vs GPS analysis) or velocity zone classification in the studies by Krustup *et al.* (2005:1243), Hewitt *et al.* (2014:1875) and Nakamura *et al.* (2016). It is important to emphasise the differences reported in distance covered when measured using different methods since a study conducted by Randers *et al.* (2010:175) proved that GPS analysis measured a 13% longer total distance covered and a 23% longer HIR distance than video analysis.

A study comparing the performance of professional female soccer players, employed in the US league but being representative of 9 different national teams from 5 different continents, with Danish elite players (participating in the Danish league) found that the national team players (professional players) performed a higher ( $p < 0.05$ ) number of HIR and sprinting bouts (154 HIR; 30 sprints) than the elite players participating on a lower level (125 HIR; 26 sprints) (Mohr *et al.*, 2008:345). The professional players thus completed 6% and 1% of the total match time performing HIR and sprinting respectively, whereas the elite players completed 4% and 1% of the total time at HIR and sprinting (Mohr *et al.*, 2008:345). It was, therefore, concluded that the professional players performed 28% more HIR and 24% more sprinting than the elite Danish players (Mohr *et al.*, 2008:346).

Using video analysis, Gabbett and Mulvey (2008:546) found that the central defenders performed less HIR (1.2 km) than the midfielders (1.6 km) and forwards (1.6 km) and that the forwards accomplished more sprinting ( $> 25$  km/h) (0.5 km) than both the midfielders (0.4 km) and the defenders (0.3 km). Similar results were reported by Mohr *et al.* (2008:347) in that defenders performed less ( $p < 0.05$ ) HIR (1.1 km) compared with both the midfielders (1.6 km) and the forwards (1.6 km). In agreement with these findings, Australian national-level defenders completed less ( $p = 0.001$ ) distance at HIR (1 744 m) than midfielders (2 792 m) who in turn, covered more distance than forwards (2 272 m) when measured by GPS analysis (Hewitt *et al.*, 2014:1877). In contrast to these findings, forwards covered the greatest distance by means of HIR in a study by Vescovi and Favero (2014:407) in both the first half (475 m) and the second half (454 m) of matches when compared with midfielders (384 m and 378 m) and defenders (384 m and 364 m) who produced similar results. The study by Vescovi and Favero (2014) was, however, conducted on sub-elite players, which could possibly explain the differences in the results obtained per position.

Further, Mohr *et al.* (2008:347) claimed that elite defenders sprinted shorter ( $p < 0.05$ ) distances (0.3 km) than forwards (0.5 km), whereas midfielders sprinted a distance of 0.4 km when measured using video analysis. Even though the defenders in the study by Hewitt *et al.* (2014:1877) also covered a shorter distance (188 m) by means of sprinting than both the midfielders (392 m;  $p = 0.001$ ) and forwards (388 m;  $p = 0.006$ ), the midfielders achieved the highest total sprinting distance. This is in contrast to the studies of Gabbett and Mulvey (2008:546) and Mohr *et al.* (2008:347), in which the forwards completed the greatest sprinting distance. Among sub-elite female players, forwards also sprinted the furthest distances during both the first half (146 m) and the second half (193 m), which was followed by defenders producing the second-best results (first half: 131 m; second half: 135 m) (Vescovi & Favero, 2014:407). Sub-elite midfielders sprinted the shortest distances in both the first half (87 m) and the second half (110 m), resulting in a difference in sprinting performance in the first half when comparing midfielders with both forwards and defenders (Vescovi & Favero, 2014:407). Vescovi and Favero (2014:412) claim that the differences observed when comparing results with other studies may be due to their sample being small in number in terms of players completing an entire match, which is a result of the substitution rule of the US NCAA in which unlimited substitutions are permitted in the second half. It is also important to note that a possible explanation for these contrasting findings may be differences in playing formations, which have an impact on the movement profile of players (Hewitt *et al.*, 2014:1878). Although there are several contextual factors that could influence match demands, the biggest factor for differences between studies are the various velocity thresholds used for sprinting across the studies cited.

Hewitt *et al.* (2014:1879) acknowledged that the distances players cover at different intensities may be influenced by player density because this can influence and reduce the amount of space available for running since there are more players in a smaller part of the playing field. A team that dominates possession and forces the opposition towards their own goal line causes more players to be in one half of the field, thereby decreasing the space available for running, whereas playing against an opponent of relatively equal strength results in an increase in the opportunities to move from the offensive to the defensive half, decreasing player density and increasing running space (Hewitt *et al.*, 2014:1879).

Vescovi *et al.* (2011:674) proved that in female soccer players, the sprint ability of the players differs across a wide age range. The study further noted that sprint ability stabilized by 16 years in female soccer players and therefore a generic velocity threshold for motion analysis could be used from this age onward (Vescovi *et al.*, 2011:674). Thus, the speed zones used to classify sprints for different standards have implications for motion-analysis studies (Vescovi,

2012a:1259). Vescovi (2012a:1260) is of the meaning that previously published reports by Krustup *et al.* (2005), Mohr *et al.* (2008) and Andersson *et al.* (2010b) indicate irregular assessment of high-speed running distance in female soccer, which is surprising because identical methods such as video recording, computerised coding and speed thresholds were reported in each paper. It was noted that the velocity threshold used for classifying sprinting (25 km/h) was similar to that used for male soccer players (Bradley *et al.*, 2009:160). This led to Vescovi (2012a:1260) researching more specific sprint characteristics of female soccer players during competitive games using 5 Hz GPS devices. Vescovi (2012a:1261) classified four sprinting zones: Zone 1 (18–20.9 km/h); Zone 2 (21–22.9 km/h); Zone 3 (23–24.9 km/h); and Zone 4 (>25 km/h). The main findings of the study demonstrated that midfielders had shorter mean sprint duration, lower sprint distance and lower maximum speed than forwards and defenders (Vescovi, 2012a:1261). The forwards also performed more sprints per game (43) than midfielders (31) and defenders (36) (Vescovi, 2012a:1261). Nakamura *et al.* (2016) also reported more sprints (23) among the forwards compared to the other playing positions. In addition, the study reported a total distance of 9.9 km covered during matches, which is similar to results previously reported by other authors (Krustup *et al.*, 2005; Mohr *et al.*, 2008; Andersson *et al.*, 2010b). Vescovi (2012a:1262) also reported a total mean distance covered above 18 km/h during a match for forwards (657 m), midfielders (447 m) and defenders (545 m). These were in accordance with the results previously published by Mohr *et al.* (2008) but greater than those published by Krustup *et al.* (2005) and Andersson *et al.* (2010b). In conclusion, the study by Vescovi (2012a:1263) claims that when using 18 km/h and 25 km/h as the lower and upper limits of sprint performance, 11% of the sprint distance is eliminated. The authors also state that the use of 25 km/h as the lower threshold is possibly too high, given that many players may not surpass this speed even though they are sprinting, which can lead to the incorrect observation of little or even no sprinting during a game (Vescovi, 2012a:1263).

Elite-level female soccer matches are characterised by work rates in the range of 108–119 m/min (Mohr *et al.*, 2008:346; Andersson *et al.*, 2010b:914; Bradley *et al.*, 2014:163) although a maximum of 126 m/min was observed by Krustup *et al.* (2005:1245). A study on sub-elite female soccer players reported a work rate in the range of 96–107 m/min, with individual players achieving 120 m/min to 130 m/min (Vescovi & Favero, 2014:408). Positional distinctions are also evident, with the highest work rate observed among the central midfielders (124 m/min), wide midfielders (121 m/min) and forwards (120 m/min), and the lowest work rate noted among the fullbacks (119 m/min) and central defenders (114 m/min) (Bradley *et al.*, 2014:163). Once again, the higher work rate performed by midfielders can be justified by the linking role that these players fulfil during a match (Di Salvo *et al.*, 2007:225).

Since elite female soccer consists of multiple brief and intense activities separated by LI exercise, good and poor physical performance can be differentiated in terms of the amount of HIR performed during matches (Krustrup *et al.*, 2005:1246). Since the physical requirements of a match are influenced by the styles of play and formations of both teams, it should be emphasised that the type and amount of running required during a match will be influenced accordingly (Hewitt *et al.*, 2009:226). It was also mentioned that the technical and tactical abilities of players influence the running requirements during a match, that is, a team having control over the ball for long periods during a match and maintaining possession may not be required to cover as much distance as the team without the ball (Hewitt *et al.*, 2009:227). Other contributing factors include match importance, score line, location and recovery days between matches (Paul *et al.*, 2015:516).

#### **2.5.1.4 Player load imposed on soccer players and analysis of accelerations and decelerations during matches**

According to Dalen *et al.* (2016:351), there are important limiting factors to consider when evaluating the physiological profile of players on the basis of two-dimensional (2-D) analysis, which is characteristic of most of the match-analysis tools in elite soccer. With 2-D systems, expended energy is only computed when a player travels from one location to another (Dalen *et al.*, 2016:352). Due to this, many of the typical soccer activities have been neglected because although these soccer-specific movements can result in considerable physical stress, the distance covered or speed has been classified as low (Dalen *et al.*, 2016:352). Dalen *et al.* (2016:357) further explain that HI bouts such as jumping, tackling, colliding, accelerating and decelerating, passing, shooting and movements such as sideways and backward running may be classified as low-speed movements despite the high physical strain these activities place on the player.

Player load is a representation of total body load and is expressed in arbitrary units (Barron *et al.*, 2014:735). Barron *et al.* (2014:736) assessed the player load of youth male soccer players through the use of 5 Hz GPS devices equipped with a 100 Hz accelerometer located securely between the scapulae in a custom-made harness. This GPS and accelerometer technology was also used by Scott *et al.* (2013:196) to determine player load of professional male soccer players. Scott *et al.* (2013:197) used Logan Plus software and calculated player load through the use of the following equation:  $(a_{y1}-a_{y-1})^2 + (a_{x1}-a_{x-1})^2 + (a_{z1}-a_{z-1})^2$ , where  $a_y$ =anteroposterior acceleration,  $a_x$ =mediolateral acceleration and  $a_z$ =vertical acceleration. An important consideration when using

this method is that the harness must be sufficiently secured to prevent the collection of erroneous data (Barron *et al.*, 2014:740).

Dalen *et al.* (2016:353) assessed player load through the use of TMA and triaxial accelerometer sensors mounted in a specially designed belt wrapped around the player's waist. Triaxial accelerometers are highly responsive motion sensors that record acceleration of body movement in three dimensions (Dalen *et al.*, 2016:352). Player load was calculated as:  $([X^2] + [Y^2] + [Z^2])/800$ , where X=sideways, Y=forwards, and Z=vertical acceleration (Dalen *et al.*, 2016:353). A mean accelerometer player load of 558 (in the range of 278–1 053) was recorded for elite male soccer players during a total of 29 field-based training sessions consisting of 60-min to 90-min durations (Scott *et al.*, 2013:199). Dalen *et al.* (2016:354) reported a higher player-load value (13 327), although this was measured over the full duration of a soccer match.

Player load is also found to differ between positions (Barron *et al.*, 2014:737). A difference ( $p \leq 0.04$ ) was found between the player load of central midfielders (991) and central defenders (745) when measured among youth male soccer players (Barron *et al.*, 2014:737). Player-load values of 892, 866 and 782 were reported for forwards, wide midfielders and wide defenders respectively (Barron *et al.*, 2014:739). Dalen *et al.* (2016:356) found that following a full match, wide midfielders, central midfielders, central defenders and forwards had a 26%, 18%, 12% and 8% higher player load respectively than fullbacks. Due to correlations found between player load and methods used to assess the internal training load and the Session Rating of Perceived Exertion (RPE), Scott *et al.* (2013:200) suggest that player load is an acceptable measure of external training load and is largely related to a player's physiological and perceptual responses to a training stimulus. In order to design training programmes specific to the different playing positions, an understanding of the different ways in which players in these different positions achieve load is necessary (Dalen *et al.*, 2016:358). Since player load is achieved by players from different positions in a variety of ways, specificity should be applied in designing training programmes with distinct emphasis on the physical components required to achieve a stimulating load in relation to each position's requirements (Dalen *et al.*, 2016:358).

An important factor regarding player load involves movements with accelerations and decelerations (Dalen *et al.*, 2016:352). According to Izzo and Lorenzo (2015:250), the most frequent actions performed in soccer are accelerations and decelerations. Dalen *et al.* (2016:357) reported that a total of 12–16% of the total player load in their study accumulated from accelerations and decelerations, indicating the importance of these movements in total player load during a match. Furthermore, Izzo and Lorenzo (2015:250) describe that the overall quality

of a player, including dribbling capacity, ability to win a 1-vs-1 contest for the ball and ability to score goals, is dependent on the player's acceleration and deceleration capacity. Accelerations are also found to be more common than decelerations (64% vs 35%) (Barron *et al.*, 2014:740). Carling *et al.* (2008:853) proposed that when a player is required to sprint in a match, the player's capability to accelerate may be more crucial than his/her maximal running speed since the technical demands of the match rarely require a player to attain maximal speeds. Therefore, improving a player's performance with regard to accelerating could result in improvements in other aspects such as being first to the ball or escaping a marker (Carling *et al.*, 2008:853).

Quantification of the acceleration and deceleration demands of team sports through the use of an applicable measuring device would greatly extend the existing body of knowledge and add great value to the research field (Varley *et al.*, 2012:121). Global positioning system technology can be utilised to assess and provide a more accurate analysis on the acceleration and deceleration of the entire activity performed rather than only assessing the running speed using timing gates (Izzo & Lorenzo, 2015:250). A study by Akenhead *et al.* (2013:557) on elite male soccer players using 10-Hz GPS units classified accelerations and decelerations into different threshold zones, namely total acceleration ( $T_{ACC.} >1\text{m/s}^2$ ), low acceleration ( $L_{ACC.} 1 \text{ to } 2 \text{ m/s}^2$ ), moderate acceleration ( $M_{ACC.} 2 \text{ to } 3 \text{ m/s}^2$ ), high acceleration ( $H_{ACC.} >3 \text{ m/s}^2$ ), total deceleration ( $T_{DEC.} <-1 \text{ m/s}^2$ ), low deceleration ( $L_{DEC.} -1 \text{ to } -2 \text{ m/s}^2$ ), moderate deceleration ( $M_{DEC.} -2 \text{ to } -3 \text{ m/s}^2$ ) and high deceleration ( $H_{DEC.} <-3 \text{ m/s}^2$ ).

Similar zones were used in an earlier study on male players employing video analysis (Osgnach *et al.*, 2010:173). Barron *et al.* (2014:737) classified decelerations into: Zone 1 (-20 to -5  $\text{m/s}^2$ ); Zone 2 (-5 to -4  $\text{m/s}^2$ ); Zone 3 (-4 to -2  $\text{m/s}^2$ ); and Zone 4 (-2 to 0  $\text{m/s}^2$ ) and accelerations into: Zone 5 (0 to 2  $\text{m/s}^2$ ); Zone 6 (2 to 4  $\text{m/s}^2$ ); Zone 7 (4 to 5  $\text{m/s}^2$ ); and Zone 8 (5 to 20  $\text{m/s}^2$ ). Akenhead *et al.* (2013:559) reported that an average of 18% of the total distance covered during a match was by accelerating or decelerating at a rate of more than 1  $\text{m/sec}^2$ . Further analysis showed that 7%, 4% and 33% of the total distance was covered at 1–2  $\text{m/s}^2$ , 2–3  $\text{m/s}^2$  and  $>3 \text{ m/s}^2$  respectively (Akenhead *et al.*, 2013:559). Barron *et al.* (2014:737) found that low-intensity movements performed in Zone 4 and Zone 5 accounted for 93% of the total distance covered. Positional differences were noted in deceleration Zone 1, with wide midfielders covering more distance than wide defenders, central defenders and central midfielders ( $p \leq 0.00$ ;  $d = 0.55$ ) and forwards covering more distance than central defenders ( $p \leq 0.04$ ;  $d = 0.55$ ) (Barron *et al.*, 2014:737).

Barron *et al.* (2014:737) reported a similar finding in deceleration Zone 2 ( $p \leq 0.02$ ;  $d = 0.49$ ). In deceleration Zone 3, wide midfielders and forwards covered more distance than central defenders ( $p \leq 0.04$ ;  $d = 0.32$ ) (Barron *et al.*, 2014:737). Wide midfielders also covered more distance than central defenders ( $p \leq 0.05$ ;  $d = 0.33$ ) and forwards ( $p \leq 0.05$ ;  $d = 0.26$ ) in acceleration zones 7 and 8 respectively (Barron *et al.*, 2014:737). These findings were denoted to the combined offensive and defensive responsibilities of wide midfielders and wide defenders (Barron *et al.*, 2014:739). It has further been highlighted that differences in playing formation, playing standard, effective playing time and score line have an influence on the positional activity profiles (Barron *et al.*, 2014:739).

### **2.5.1.5 Fatigue indicators during match play and utilization of pacing strategies**

Fatigue can be described as a reduction in performance owing to the need for continuous effort and is usually noted in soccer by a deterioration in player work rate towards the end of a match (Barbero Álvarez *et al.*, 2008:8). According to Mohr *et al.* (2005:598), the exercise of top-class soccer players declines in periods during a match, which is most likely to be caused by the onset of fatigue. Waldron and Highton (2014:1651) claim that players are able to determine and modulate their energy output depending on the nature of the match. Mohr *et al.* (2003:526) refer to the term “temporary” fatigue, also known as “transient” fatigue (Alghannam, 2012:68), which refers to periods (typically five min) of reduced running intensity that are below the average match intensity and occur immediately after the most intense periods of the match. A complete recovery in running intensity may be attained after that specific period (Waldron & Highton, 2014:1646).

A 4.8% decrease in distance covered between the first and second half of a match was recorded through GPS analysis in a study on female Australian national team players (4 936 m to 4 695 m) (Hewitt *et al.*, 2014:1876). A decrease ( $p < 0.05$ ) in total distance from the first to the second half was also noted by Mohr *et al.* (2008:345) and Andersson *et al.* (2010b:914). In addition, Vescovi and Favero (2014:407) reported lower work rates for the players in their study when the first half of a match was compared with the second half. A study examining the locomotor characteristics of sub-elite female players from different positions found that all three groups (forwards, midfielders and defenders) covered less total distance in the second half of a match compared with the first half (Vescovi & Favero, 2014:407). The performance of forwards decreased from 5 232 m to 5 065 m, and midfielders decreased from 5 186 m to 4 939 m although these results were not significant (Vescovi & Favero, 2014:407). The defenders covered less ( $p < 0.05$ ) distance than the forwards and midfielders, and a decrease from 4 878 m to 4 618 m was observed from the first half to the second half (Vescovi & Favero, 2014:407). Defenders thus produced lower

( $p < 0.05$ ) values of work rate during both the first half (100 m/min) and the second half (96 m/min) when compared with midfielders (first half: 106 m/min; second half: 103 m/min) and forwards (first half: 107 m/min; second half: 106 m/min) (Vescovi & Favero, 2014:407).

Reports on distance covered at LI showed that a further distance was covered by means of walking in the first half compared with the second half by forwards (1 482 m vs 1 540 m), midfielders (1 516 m vs 1 647 m) and defenders (1 540 m vs 1 586 m) (Vescovi & Favero, 2014:407). Distances covered by means of jogging and LIR also decreased for the forwards (667 m vs 570 m; 1 655 m vs 1 483 m), midfielders (677 m vs 639 m; 1 675 m vs 1 446 m) and defenders (607 m vs 567 m; 1 442 m vs 1 292 m) (Vescovi & Favero, 2014:407). The decline in HIR of elite female players at the end of a match is described as a result of fatigue (Krustrup *et al.*, 2005:1246). Krustrup *et al.* (2005:1244) established that the distance covered at HIR decreased by 30.0% (0.27 km to 0.19 km) and 34% (0.24 km to 0.16 km) from the first to the last 15-minute period of the first and second half of the match respectively. In agreement with these results, a decrease of 26% in HIR was observed during the last 15 minutes of international-level female matches compared to the first 15 minutes, as well as an increase of 4% in LIA (Hewitt *et al.*, 2014:1878). It was further noted that elite female players performed the least amount of HIR in the last 15-minute periods of the first and second halves (Krustrup *et al.*, 2005:1246). A decrease ( $p < 0.05$ ) in performance was also observed in a comparison between the first and the second half in terms of bouts of LIR (29 vs 26.5), HIR (6.5 vs 5.4) and sprinting ( $p < 0.05$ ) (1.2 vs 1) of professional female players (Mohr *et al.*, 2008:345). Similar results were found among elite Danish players for LIR (29.7 vs 27.9), HIR (4.5 vs 4.3) and sprinting (1 vs 0.9) from the first to the second half, which were also reported to be significant ( $p < 0.05$ ) (Mohr *et al.*, 2008:346). High-intensity running and sprinting decreased in terms of first- and second-half performance from 0.9 km to 0.7 km and from 0.25 km to 0.21 km respectively among the national team players and decreased from 0.68 km to 0.62 km and 0.2 km to 0.17 km respectively among the elite players (Mohr *et al.*, 2008:346). A similar tendency was reported for female Australian national team players, with a decrease from 1 224 m to 1 163 m in performing HIR and from 173 m to 165 m in sprinting from the first to the second half (Hewitt *et al.*, 2014:1876).

Mohr *et al.* (2008:344) sub-divided their match data into smaller time periods (5-min, 15-min, 45-min and 90-min periods) in order to analyse further the activity profiles of female players at different levels during a soccer match. A different approach was followed by Hewitt *et al.* (2014:1876) by dividing the total match time into periods of 0–15 min, 15–30 min, 30–45 min, 60–75 min and 75–90 min. Carling *et al.* (2008:852) proposed that an alternative means for comparing the overall physical contribution of players is to calculate a relative measurement of

performance by correcting the absolute value (total distance covered) for a match to a minute-by-minute analysis of distance covered. In a study by Hewitt *et al.* (2014:1876), the GPS analysis revealed that female players covered less distance per 15-minute period as the match progressed, with a decline observed in the first half from 0–15 min (1 699 m) to 15–30 min (1 570 m) to 30–45 min (1 567 m), and again from 45–60 min (1 595 m) to 60–75 min (1 506 m), with the lowest distance of the entire match covered in the last 75–90 min period (1 458 m). Hewitt *et al.* (2014:1876) reported a decline from the start to the end of each half in considering the three 15-minute periods per half and found a significant difference ( $p < 0.05$ ) in total distance covered between the 0–15 min (1 699 m) period and both the 60–75 min (1 506 m) and 75–90 min (1 458 m) periods respectively. Professional players in the US league performed 27–57% (0.21 km) ( $p < 0.05$ ) less HIR in the final 15-minute period of the match than during the first four 15-minute periods (0.27 km to 0.33 km) (Mohr *et al.*, 2008:346). Australian national team players also performed less ( $p = 0.022$ ) HIR in the second last (378 m) and final 15-minute (356 m) periods in comparison with the first four 15-minute periods (478 m; 384 m; 382 m; and 429 m) (Hewitt *et al.*, 2014:1876).

In the study by Mohr *et al.* (2008:346), distance covered by means of sprinting was also shorter ( $p < 0.05$ ) during the last 15-minute period (0.05 km) in comparison with the first four 15-minute periods (0.07 km to 0.08 km). Elite Danish female players also achieved a lower ( $p < 0.05$ ) distance in HIR in the final 15 minutes of both halves compared with the first and second 15-minute intervals and furthermore, covered a 16–41% shorter ( $p < 0.05$ ) distance in HIR in the five last 15-minute periods (0.16 km to 0.23 km) than in the first 15-minute period (0.28 km) (Mohr *et al.*, 2008:346). Moreover, the players sprinted further in the first 15-minute period than in the last 15-minute period of the first half (0.09 km vs 0.05 km) and the second half (0.07 km vs 0.04 km) (Mohr *et al.*, 2008:346). Although differences in distances covered by means of sprinting between the first (173 m) and second half (165 m) of matches were noted by Hewitt *et al.* (2014:1876), these distances did not differ and neither did the distances covered per 15-minute time period, which were 67 m (0–15 min), 56 m (15–30 min), 50 m (30–45 min), 59 m (45–60 min), 53 m (60–75 min) and 53 m (75–90 min). This may be due to a decline in HIR and the subsequent increase in LIA, which may have given the players more recovery opportunities and resulted in the maintenance of the distance covered by means of sprinting (Hewitt *et al.*, 2014:1878). Regardless of level of participation, less HIR is performed towards the end of a match, suggesting the occurrence of fatigue towards the end of a match (Mohr *et al.*, 2008:348). Comparisons among female players in different positions showed that all positions (forwards, midfielders and defenders) performed less ( $p < 0.05$ ) HIR and sprinting in the second half of a match than in the first half (Mohr *et al.*, 2008:347). The results, therefore, indicate that female

players fatigue temporarily during a match as well as towards the end of a match (Mohr *et al.*, 2008:347).

According to Mohr *et al.* (2008:348), the higher the level of participation, the greater is the running intensity during matches. As a result, a soccer player needs the ability to perform HI exercises repeatedly (Mohr *et al.*, 2008:347). Gabbett *et al.* (2013:132) reported an average of 5.1 RSA bouts performed per elite female soccer player during a match, with some players performing no repeated-sprint bouts and others performing up to 23 bouts. An average sprint duration of 2.1 s throughout the various RSA bouts was noted, with the greatest number of sprints recorded in a single bout being seven (Gabbett *et al.*, 2013:132). In another study that examined the RSA of elite female soccer players, an average of 4.8 bouts per player per match was recorded, and a mean number of 3.4 sprints performed per sprint bout (Gabbett & Mulvey, 2008:549). Even though sprint duration remained relatively constant across short and long RSA bouts, the mean duration of recovery increased progressively with a greater number of sprints performed per bout (Gabbett *et al.*, 2013:132).

It was also noted that large differences exist in the recovery durations between national and international matches for RSA bouts involving three and four efforts, indicating that national matches are characterised by greater recovery durations (Gabbett *et al.*, 2013:134). Performance characteristics such as the ability to gain possession of the ball or not concede a goal are influenced by a player's ability to perform HI sprints, which are also considered distinguishing factors between players of a higher and a lower standard (Izzo & Lorenzo, 2015:251). A study by Krustup *et al.* (2010:440) proved that RSA and intense intermittent exercise performance of female soccer players are impaired towards the end of soccer matches, thus confirming that these deviations in work rate during the final phases of matches are a result of match-induced fatigue. This was evident in a study by Gabbett *et al.* (2013:133) who found that the number of RSA bouts performed decreased from the first to the second half (3.0 bouts vs 2.1 bouts), with the greatest frequency of RSA bouts performed during the first 15 minutes of the match. During the first 15 minutes following the half-time break, there were also more RSA bouts performed in comparison with the second and last 15-minute periods of the first half (Gabbett *et al.*, 2013:134). Good performance is closely connected to the level of fatigue (Izzo & Lorenzo, 2015:251). It is believed that players who are able to perform repeated sprints at an equal or very similar intensity are, as a result, likely to perform better over extended periods of time (Izzo & Lorenzo, 2015:251). Although Gabbett *et al.* (2013:136) found no reduction in RSA from the first to the second half, the amount of LI recovery between repeated-sprint efforts increased, which could explain the

maintenance in repeated-sprint performance. Therefore, the training of female players should place emphasis on improving the ability to recover from intense exercise (Mohr *et al.*, 2008:348).

Furthermore, position-specific training programmes may be required to prepare some players adequately for the high amount of RSA required in matches (Gabbett *et al.*, 2013:136). Female central midfielders performed more RSA bouts (10.0) in international matches than wide midfielders (6.0), forwards (3.6) and defenders (3.2) (Gabbett *et al.*, 2013:133). Also, in national matches, female central midfielders performed the most RSA bouts (7.4), followed by forwards (6.0), defenders (5.3) and wide midfielders (1.0) (Gabbett *et al.*, 2013:133). Similar findings were reported by Gabbett and Mulvey (2008:546), with midfielders performing more bouts per player (6.0) in comparison with forwards (4.7) and defenders (4.0). The recovery between sprints was however, shorter for defenders (4.3 s) compared with midfielders (6.6 s) and forwards (6.7 s) (Gabbett & Mulvey, 2008:546).

Another concept being researched is the use of pacing strategies by players, which can be mistakenly interpreted as the manifestation of fatigue (Paul *et al.*, 2015:517). The reduction in performance of players observed from the first to the second half of a match can thus either be attributed to the effect of accumulated fatigue or to the player applying a subconscious pacing strategy (Edwards & Noakes, 2009:2). The occurrence whereby brief periods of 'peak' intensity are consistently followed by significant brief periods of reduced intensity may be described as complex and planned strategies by the player (Waldron & Highton, 2014:1651). Various pacing profiles exist such as 'positive strategy', 'even-paced strategy' and 'negative strategy', which depend on the structure of the sport and the duration of exercise bouts and ultimately characterises match-running performance (Waldron & Highton, 2014:1651).

Edwards and Noakes (2009:10) further suggested a model for pacing based on macro-, meso- and micro-pacing strategies. The macro-pacing strategy is pre-determined before the match and can involve aspects such as finishing the match and responding to the demands of the match as required (Edwards & Noakes, 2009:10). The meso-strategy is an inter-half pacing plan, enabling up- and down-regulation of effort during a match in response to tactical and specific match considerations (Edwards & Noakes, 2009:10). Micro-pacing is a dynamic pacing plan, connecting each level of pacing strategy throughout the match and ensuring that no single factor causes the cessation of exercise (Edwards & Noakes, 2009:11). The slow-positive strategy employed by players completing an entire match involves a progressive decline in running intensity throughout the match, permitting optimal completion of a match while at the same time reserving the capacity for transient periods of HIA (Waldron & Highton, 2014:1652). The concept of pacing advances

previous notions of acute fatigue during matches and could alternatively explain the fluctuations observed in match-running performance (Waldron & Highton, 2014:1646).

According to Edwards and Noakes (2009:11), multi-level pacing plans employed by players ensure that the players are able to perform until the end of a match. While the demands of a match will require players to respond physically, players who do not pace themselves will not be able to perform until the end of the match or have energy reserves for short-term sprints during the later stages of the match (Edwards & Noakes, 2009:11). Hence, players decide how and when to respond to the diverse challenges posed during a match (Edwards & Noakes, 2009:9). According to Waldron and Highton (2014:1648), running performance during matches is self-regulated by players in response to the dynamically changing environmental stimuli. Players, therefore, possess physiological reserves, allowing them to perform HI energy expenditure when required during the match. As a result and especially when needed to play the entire match, players preserve their energy expenditure over the course of the match in an attempt to avoid fatigue (Waldron & Highton, 2014:1648). This theory is supported by Bradley and Noakes (2013:1635) who noted that players who covered the lowest total distances during the first half of a match had the capacity to maintain match-running performance during the second half. It is also explained that subconscious physiological factors influence conscious behavioural decisions in regulating effort, such as a player covering an opponent's movement rather than intercepting, walking rather than jogging and passing the ball to a team member rather than dribbling (Edwards & Noakes, 2009:8). Players, therefore, down-regulate their energy output for later periods of the match, which is viewed as one method of pacing (Waldron & Highton, 2014:1651). This was proved in a recent study in which an increase in distance covered during the final 10 minutes of a match was observed, indicating an end spurt towards the end of the match and implying that performance during the first half influences the pacing strategy of players playing a full match (Sparks *et al.*, 2016:129).

An area that has not received much attention in soccer is the analysis of match demands throughout a tournament in which matches are played on consecutive days. Some competition structures exist in which playing matches on consecutive days or two days apart from one another is required, and warrants research to provide scientific support to coaches in preparing their players for competitions structured in this manner. Other team field-sport have investigated the effect of fatigue on match performance throughout a tournament (Higham *et al.*, 2012; Jennings *et al.*, 2012; Furlan *et al.*, 2015; Inglis & Bird, 2017). The physiological stress experienced by players result in accumulated fatigue, which leads to a decrease in performance (Marqués-Jiménez *et al.*, 2017:55). Increased match intensity and frequency emphasises the necessity to

recover sufficiently between matches for peak performance (Andersson *et al.*, 2008:372). In order to perform optimally, appropriate recovery interventions in competitive tournaments and between matches is therefore important (Andersson *et al.*, 2008). Between match analysis of field hockey and rugby matches show generally small to large reductions in match variables (Higham *et al.*, 2012; Jennings *et al.*, 2012; Inglis & Bird, 2017). According to Jennings *et al.* (2012), players have limited time to recover before the next match, and therefore the ability to maintain exercise intensity throughout a tournament could be of importance, since there is a possibility that players may experience accumulated fatigue.

## **2.5.2 Quantifying internal demands of match play**

Soccer requires players to possess good technical, biomechanical, tactical, psychological and physiological characteristics (Sjokvist *et al.*, 2011:1726). The areas of psychology and physiology are, therefore, of critical importance from a fitness perspective (Sjokvist *et al.*, 2011:1726). Methods used for describing internal match demands include HR monitoring (Bendiksen *et al.*, 2013), the use of an RPE scale (Coutts *et al.*, 2009) and the measurement of blood lactate concentration following an activity or task (Baumgart *et al.*, 2014).

### **2.5.2.1 Determining internal match demands through heart rate monitoring**

The measurement of HR is often used as an indirect measure of exercise intensity (Datson *et al.*, 2014:1228). A review by Stølen *et al.* (2005:503) explains that average work intensity, which is measured as a percentage of maximal HR ( $HR_{max}$ ), is close to the anaerobic threshold during a 90-minute soccer match (80–90% of  $HR_{max}$ ). Average HR and peak HR values of 84–89% and 98–100% of  $HR_{max}$  respectively have been reported for female soccer players during matches (Andersson *et al.*, 2008; Krstrup *et al.*, 2010; Ohlsson *et al.*, 2015). Maximal HR values of 187 bpm and 185 bpm were reported for international and domestic league matches of female players respectively (Andersson *et al.*, 2010b:917). A similar  $HR_{max}$  was reported for elite Danish female players (186 bpm) by Krstrup *et al.* (2005:1244), corresponding with 97% of  $HR_{max}$  when assessed with a laboratory treadmill running test. The highest  $HR_{max}$  reported for an individual player during a match was 205 bpm (Krstrup *et al.*, 2005:1246). A more recent study by Krstrup *et al.* (2010:439) recorded average and peak HR values of 168 bpm (86% of  $HR_{max}$ ) and 194 bpm (98% of  $HR_{max}$ ) during a match.

During international matches, an average HR of 162 bpm has been recorded, with similar values reported for the first half (164 bpm) and second half (162 bpm) (Andersson *et al.*, 2010b:917). Similar results were found in domestic league games, with values of 164 bpm, 159 bpm and

163 bpm being reported for the first half, second half and total match respectively, thereby indicating no difference in level of competition in terms of HR response (Andersson *et al.*, 2010b:917). The players had an average of between 84% and 86% of their peak HR throughout the matches in both the international and domestic league matches (Andersson *et al.*, 2010b:917). No difference in average HR was noted in a study by Krstrup *et al.* (2010:439) between the first half (170 bpm) and the second half (167 bpm) of a match with elite female players. Elite Danish players in a different study also recorded an average HR of 167 bpm, corresponding to 87% of HR<sub>max</sub> (Krstrup *et al.*, 2005:1244). A review by Datson *et al.* (2014:1228) claimed average and peak HR values of 86.0% and 98.0% of HR<sub>max</sub> respectively. When split into smaller time periods, Andersson *et al.* (2010b:917) found that on international level, HR was higher ( $p < 0.05$ ) in the 15–30 min period (167 bpm) compared with the 0–15 min (162 bpm), 45–60 min (158 bpm) and 75–90 min (162 bpm) periods. It was also noted that in domestic league matches, HR in the 15–30 min period (163 bpm) was higher ( $p < 0.05$ ) than in the 45–60 min period (158 bpm) (Andersson *et al.*, 2010b:917). Krstrup *et al.* (2010:439), however, could not find any significant differences in the average HR of elite female players between any of the 15-minute periods and reported an average of 171 bpm for the final 75–90 min period.

In summary, Krstrup *et al.* (2005:1244) reported that it appears that all outfield players have a high aerobic loading throughout a match, with periods corresponding to near-maximal values and defenders, midfielders and attackers performing at 86–88% of their HR<sub>max</sub>. Krstrup *et al.* (2005:1247), however, explain that their findings indicate that the aerobic energy system is highly tasked even for players possessing superior physical capacity and, therefore, the activity profile and energy used during a match is adjusted according to each player's physical ability.

### **2.5.2.2 Blood lactate concentration**

According to Datson *et al.* (2014:1229), there is little information pertaining to the anaerobic energy contribution in match play of female soccer players. Anaerobic capacity can be measured through the evaluation of blood lactate (Datson *et al.*, 2014:1229). When one engages in exercise of increasing intensity, blood lactate concentration usually increases rapidly at a power output between 50% and 70% of the maximal workload (Chmura & Nazar, 2010:287). Elite female players exhibited average blood lactate concentrations of 5.1 mmol/L and 2.7 mmol/L following the first and second halves of matches respectively (Krstrup *et al.*, 2010:439). Despite the low value recorded after the second half, it was reported that match intensity and aerobic loading was still high in the final quarter of the match (Krstrup *et al.*, 2010:440). Krstrup *et al.* (2010:440) proposed that muscle glycogen depletion occurs near the end of a female soccer match, and this

could influence the ability to perform intense intermittent exercise but not jumping performance since this activity is too short to have a substantial glycolytic contribution to energy production. Throughout the execution of a soccer-specific simulation test, blood lactate concentrations of 4.7 mmol/L, 4.8 mmol/L and 4.7 mmol/L were measured after 15 minutes, 30 minutes and 45 minutes (considered as the first half) respectively, and measurements of 4.0 mmol/L, 3.6 mmol/L and 4.9 mmol/L were measured after 15 minutes, 30 minutes and 45 minutes into the second half, although no differences were noted between the first and the second halves (Bendiksen *et al.*, 2013:1437). Bendiksen *et al.* (2013:1440) explained that this constant level of blood lactate concentration observed in the particular study may be due to the fact that total distances of HIR and sprinting were kept constant in the soccer simulation test.

It is important to emphasise that measured blood lactate concentrations are, to a great extent, dependent upon the activity pattern of the player in the five minutes preceding blood sampling (Stølen *et al.*, 2005:509), which may lead to the under- or overestimation of overall match demands (Datson *et al.*, 2014:1229). The high blood lactate concentrations observed in soccer may be a reflection of an accumulated or balanced response to the numerous high-intensity activities performed (Bangsbo *et al.*, 2006:667). Furthermore, the rate of lactate removal depends on different factors, including lactate concentration, activity during the recovery period and the aerobic capacity of the player (Stølen *et al.*, 2005:509). Consequently, players with a higher  $\dot{V}O_{2max}$  may have lower blood lactate concentrations due to an enhanced recovery from high-intensity intermittent activity (Tomlin & Wenger, 2001:9). It is also noted that players may have similar blood lactate concentrations while exercising at a higher intensity as players possessing a lower level of fitness (Stølen *et al.*, 2005:509). A challenge, however, is the inherent difficulties in obtaining blood lactate measurements during a soccer match (Bendiksen *et al.*, 2013:1431).

### **2.5.2.3 Rating of perceived exertion**

Rating of perceived exertion is used to assess a player's psychological perception of a particular session (Sjokvist *et al.*, 2011:1728). In an attempt to overcome the challenges of team-based training, it has been suggested that an uncomplicated system should be developed to quantify each individual player's response to training (internal training load) (Alexiou & Coutts, 2008:321). This provides coaches with a tool for monitoring and consequently modifying the training according to the players' individual needs (Alexiou & Coutts, 2008:321). Measurement throughout a soccer match of male players showed that RPE values recorded in the second half (13.6) were higher ( $p < 0.01$ ) than in the first half (11.4) (Aslan *et al.*, 2012:173). Throughout the match, RPE

levels progressed when measured at 15-minute intervals and peaked at the end of the match (15 min: 10.4; 30 min: 11.5; 45 min: 12.6; 60 min: 12.7; 75 min: 13.7; 90 min: 14.5) (Aslan *et al.*, 2012:173). The study thus indicates that the players perceived the progressive periods of the match as being more strenuous (Aslan *et al.*, 2012:173). In addition, RPE levels of forwards (12.9) and midfielders (12.7) were higher than defenders (12.2) (Aslan *et al.*, 2012:173).

Alexiou and Coutts (2008:326) reported correlations ( $p < 0.01$ ) between session-RPE and three different HR-based methods for quantifying training load in elite female soccer players. Thereafter, another study reported a moderate correlation between RPE and both HR<sub>max</sub> and blood lactate concentrations (Coutts *et al.*, 2009:82). Coutts *et al.* (2009:82), therefore, claim that RPE is a valid indicator of training intensity for intermittent, aerobic, soccer-specific exercise. However, Impellizzeri *et al.* (2004:1046) recommend that due to a moderate correlation observed in their study, RPE-based methods should not be considered a valid substitute of HR monitoring and should be used in combination with HR monitoring for determining internal training load. According to Aslan *et al.* (2012:170), the measurement of RPE values throughout a soccer match can thus provide information for the internal load imposed on players and the accumulated fatigue towards the end of a match.

It is, however, still not clear how hard a player perceives he/she is working throughout a match (Aslan *et al.*, 2012:170). Another important limitation is the timing of the rating because it is important to minimise the influence of the last effort during training or during a match on the player's RPE of the whole training session or match (Impellizzeri *et al.*, 2004:1046). Foster *et al.* (2001:111) recommends taking RPE only 30 min after the session and reasoned that this approach is used so that particularly difficult or particularly easy segments toward the end of the exercise bout would not dominate the subject's rating. The importance of considering the complex interaction of many factors contributing to a player's personal perception of physical effort has also been highlighted (Borresen & Lambert, 2008:26).

## 2.6 Conclusion

The popularity of female soccer has seen a considerable increase in recent years, although there is still limited research pertaining to the diverse factors contributing to successful performance. The aim of this literature review was firstly to explore the current research related to the morphological profile of female soccer players and to discuss important aerobic and anaerobic fitness components together with technical skill characteristics deemed important for high-level participation. The influential role of fatigue on technical skill performance was also explained. The second aim was to describe the internal and external match demands experienced by female

soccer players. Differences pertaining to positional roles and demands were also elaborated upon in an attempt to make distinct classifications among different players.

Morphological factors are important for successful performance in sport. The morphological characteristics were discussed in terms of stature, body mass, skeletal lengths and breadths, skinfold measurements and somatotype characteristics. A conclusion was drawn that goalkeepers tend to be taller and heavier in comparison with players in other positions, which is believed to be related to their role of defending the goal area, while midfielders are often shorter and lighter than other players and have to fulfil a linking role between the front and back team players. Taller defending players are also crucial in assisting in the prevention of an opponent scoring a goal by jumping to head the ball if the opponent strikes the ball through the air. The higher percentage of body fat observed in goalkeepers is also attributed to their lower level of activity during matches and even during training. Again, the lower percentage of body fat among midfielders is related to their responsibilities in both defence and attack situations during a match. There is also the impression that players with a somatotype displaying a combination of high muscularity and low adiposity have the advantage of being more movable when contending for possession of the ball during a match.

Together with the morphological characteristics linked to successful performance, an evaluation of the players' aerobic and anaerobic fitness is necessary since these variables may contribute towards the outcome of the match. A high level of physical fitness provides players with the physiological basis to cope with the physical demands of a match since female soccer players typically cover a distance of approximately 10.3 km during a match. There is a scarcity of data with regard to the Yo-Yo IR1 and the RSA of female soccer players and as such, these warrant further investigation. Due to the unpredictable nature of team sports, short phases of RSA may be required on numerous occasions throughout a match, and even though it is probable that this type of activity only contributes a small proportion to the overall motion activity during competition, it may be crucial to the end result. Other anaerobic-fitness components such as the sprinting and jumping ability of players have also proved to be associated with high-level performance and are crucial in attacking situations and defending the goal. There is, however, very limited research relating to the sprinting characteristics of different playing positions.

Soccer is a free-flowing, intermittent team sport that requires the execution of diverse technical skills in a dynamic context. Technical skills considered to be essential include dribbling, passing, controlling and decision-making. A limitation in the assessment of technical skills in general is the lack of valid and reliable assessment protocols since many of the protocols involve the

assessment of technical skills in a closed situation and from a static position without the influential external factors that exist within a game. The development of the LSPT provides a valid and reliable tool for the assessment of the multi-faceted aspects of soccer and allows the assessment of the impact of fatigue on technical skill performance. A vital component in soccer is the ability to maintain good technical performance throughout match play. The shortage of research investigating the effect of fatigue on technical skill performance has led to very limited information in this particular area of interest and should be further explored since both aerobic and anaerobic fatigue could influence the accuracy and execution of technical skills. Soccer coaches are confronted by the challenge to develop the team all round in terms of physical capacity, technique, tactics and mental concentration in order to tolerate the various situations encountered during a match.

Advances in technology regarding the assessment of soccer players have led to greater opportunities to support the coaching team and players scientifically. The emergence of GPS technology allows for real-time analysis of the external movement demands during a soccer match, with devices that sample at a higher frequency being more accurate. Benefits of a GPS device are that it is portable, lightweight and can store a few hours of data. The locomotor activities of players can be assessed by GPS devices through using different movement categories. The literature review highlights the diverse classifications of movement categories previously used and the difficulty of making comparisons among female soccer players due to a shortage of studies using GPS technology.

Elite female soccer matches consist of multiple bouts of brief intense exercise separated by low-intensity activity and, therefore, good and poor physical performance can be differentiated in terms of the amount of HIR performed. The higher the level of participation in female soccer, the greater the running intensity tends to be during a match. Another new concept being researched through the use of GPS technology is player load, which is a representation of total body load and allows the assessment of sideways, forward and vertical accelerations such as jumping, tackling, passing, accelerating and decelerating as well as sideways and backward movements. These movements are often neglected with TMA or regarded as low-speed movement, even though they place high physical strain on the player and should be used in the overall assessment of players and the classification of playing positions.

Apart from the external match demands placed on soccer players, quantification of the internal match demands is also important. Factors commonly included in the assessment of internal match demands are HR monitoring, blood lactate concentration and RPE. Heart rate monitoring is often

used as an indirect measure of exercise intensity and has proved to be a useful tool. A challenge, however, regarding the assessment of blood lactate concentration includes the inherent difficulties in obtaining blood lactate measurements during a soccer match, while the logistical hindrances in the execution of RPE assessment continuously throughout a soccer match makes this an impractical method for assessing internal match demands.

Finally, fatigue is an important consideration in soccer match play. Decreases in distance covered from the first to the second half at various intensities show that players experience fatigue towards the latter part of a match and also for five minutes after an intense period of activity. Regardless of the level of participation, fatigue occurs towards the end of a match, resulting in less HIR towards the latter part of a match. Players cover less distance in the second half at HIR and cover more distance with low-intensity activity. The physical training of elite players should concentrate on increasing the ability to perform intense activity and to recover rapidly from high-intensity exercise periods.

Due to the growing popularity and number of female soccer players worldwide, there is a high demand for scientific research relating to this population and the analysis of positional roles. Based on this literature review, it is evident that results differ considerably across studies. Possible reasons for this discrepancy in results are related to gender, individual characteristics of players, levels of competition, match conditions, differences in methodology used and movement impairment due to the measuring equipment utilised. Current published literature mainly focuses on male soccer players, with a paucity of publications related to the assessment of the diverse attributes related to female soccer. Furthermore, there are limited studies focused on physical profile and match demands of female players competing on sub-elite level. This is of concern considering that sub-elite level participation and improvement forms the foundation for elite level performance through players progressing from sub-elite to elite level participation. Based on the dearth of research pertaining to the match demands of female soccer players, the researcher recommends that future studies should make use of the more advanced, reliable and time-saving GPS analysis method to classify external match demands and locomotor activities as well as employ assessment methods such as HR monitoring that focus on the internal match demands of players. As a result, knowledge and understanding of this information could assist future coaches and sport scientists in developing match-related conditioning programmes based on each player's individual demands, thereby improving players' soccer performance and match standards and promoting a positive image of the female game.

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## **CHAPTER 3**

# **COMPARISON OF THE MORPHOLOGICAL CHARACTERISTICS OF SUB-ELITE FEMALE SOCCER PLAYERS ACCORDING TO PLAYING POSITION**

This article will be submitted for publication in the Women in Sport and Physical Activity Journal. The article is included herewith in accordance with the guidelines for authors of this esteemed journal (included as Appendix E). However, to provide a neat and well-rounded final product for this thesis, the article has been edited to represent an actual published article as it would appear in this particular journal. This does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from that used in the other chapters of this thesis.

**Title:** Comparison of the morphological characteristics of sub-elite female soccer players according to playing position

**Running head:** Morphological characteristics of female soccer players

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## **ABSTRACT**

Soccer has become increasingly popular among female players worldwide. Although much is known about male soccer players, limited scientific information is available on female soccer players, in particular their morphological profile according to playing positions. The primary aim of this study was to examine if there are position-specific differences in the morphological characteristics of South African sub-elite female soccer players. A secondary aim was to utilise the morphological characteristics of South African sub-elite female soccer players to establish the foundation for a database designed to create normative standards for this level of female soccer players. The morphological features of 101 sub-elite female soccer players (age:  $21.8 \pm 2.7$  years, height:  $160 \pm 6.8$  cm, body mass:  $57.1 \pm 9.1$  kg) were assessed. Twenty anthropometric sites were used in the measurements of body composition and somatotype. The average value of body fat percentage was  $20.8 \pm 5.7\%$ . The somatotype of the overall group was 4.0–2.4–2.1. Positional differences were evident and significant ( $p \leq 0.05$ ) in morphological characteristics. Goalkeepers were taller, heavier, possessed the highest body fat percentage and showed higher values for all skinfold, breadth, girth and length measurements. Defenders showed the second-highest breadth and girth measurements. Midfielders were the shortest and the lightest players, with the lowest body fat percentage and the lowest values in most measurements. Positional groups did not differ ( $p \leq 0.05$ ) in somatotype characteristics. It was consequently concluded that morphological differences exist among soccer players in their various playing positions. The results of the study may serve as normative values for future comparisons regarding the morphological characteristics of female soccer players.

**Keywords:** anthropometry, body fat percentage, standing height, somatotype, body mass, positional groups.

## **INTRODUCTION**

A continuous increase is observed in the popularity of soccer worldwide (Sporis, Canaki, & Barisic, 2007), with female soccer experiencing a constant growth in the number of players (Jelaska, Erceg, & Jelaska, 2015). The efficiency of the game is influenced by several factors, including morphological characteristics, motor abilities, functional abilities, technical and tactical abilities and psychological factors (Erceg, Milić, Sivrić, & Košta, 2014). The profile of soccer players has therefore become a subject of decisive interest (Dillern, Ingebrigtsen, & Shalfawi, 2012). Ample literature regarding the morphological characteristics of male soccer players exists, but less is known about female players (Sedano, Vaeyens, Philippaerts, Redondo, & Cuadrado, 2009). To compete at an elite level, players need to possess morphological characteristics applicable to both the sport and to specific playing positions (Hazir, 2010). An in-depth understanding of the determinants of success such as specific morphological characteristics of players is, therefore, important for soccer coaches and sport scientists (Rogan, Hilfiker, Clarys, Clijsen, & Taeymansa, 2011) to optimize players' performance.

A few studies have recently focused on the morphological characteristics of female soccer players participating on elite and sub-elite level (Hasegawa & Kuzuhara, 2015; Mala et al., 2015; Nikolaidis, 2014). Standing height values of 161.3–171.9 cm (Mara, Thompson, Pumpa, & Morgan, 2017; Sedano et al., 2009) and body mass values of 58.3–65.3 kg have been reported for elite female soccer players (Mara et al., 2017; Sporis, Jovanovic, Krakan, & Fiorentini, 2011). Comparable values for standing height and mass have been reported for sub-elite players (Nikolaidis 2014, Vescovi, 2012). It is evident that standing height and mass differ according to playing position in female soccer (Hasegawa & Kuzuhara, 2015; Milanovic, Sporis, & Trajkovic, 2012; Sporis et al., 2011). Goalkeepers are taller (Milanovic et al., 2012) and heavier (Haugen, Tonnessen, & Seiler, 2012), with defenders also being among the taller players (Milanovic et al., 2012). Midfielders tend to be the shortest and the lightest players, followed by forwards (Sporis et al., 2007; Vescovi, Brown, & Murray, 2006). It is believed that a tall goalkeeper is advantageous in jumping to reach for a ball and defending a goal (Rogan et al., 2011), while the shorter height and lighter body mass of midfielders enable them to move more efficiently and to cover longer distances on the field (Hazir, 2010). Body fat percentage (BF%) also differs between playing positions in female soccer, with goalkeepers having the highest amount of body fat (Hasegawa &

Kuzuhara, 2015). This is possibly due to the lower level of activity required during a match (Dey, Kar, & Debray, 2010).

Skeletal length and girth measurements show a general tendency for goalkeepers to have the largest measurements, with special reference to longer leg and arm lengths compared to other playing positions (Sporis et al., 2007). There is also a trend for midfielders to be among the players with the smallest skeletal length and girth measurements, which can again be attributed to their shorter stature, lower body mass and positional role (Sporis et al., 2007). The physical characteristics of the body are ultimately used to determine somatotype (Noh et al., 2015). Three somatotype components are used to define body shape; namely endomorphy, mesomorphy and ectomorphy, and are expressed by a three-number rating (Carter, 2002). These three components were identified as relative fatness (endomorphy), musculoskeletal component (mesomorphy), and linearity (ectomorphy) (Carter, 2002). Mesomorphy is generally the most predominant somatotype component among soccer players (Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007). An ectomorphic mesomorph body type is advantageous for actions requiring speed, power and endurance, which are vital components for soccer performance (Adhikari & Nugent, 2014).

Morphological characteristics are viewed as important considerations in the selection process for team position (Sporis et al., 2007). Despite this fact, the morphological characteristics of female soccer players have not been clearly defined in literature. Due to a shortage of related studies, a need exists for the establishment of normative data for female players. To the authors' knowledge, no information exists on female soccer players in South Africa that describes their morphological characteristics in accordance with playing position. Differences or comparisons in data found in relation to previous research are essential for designing individualized training programmes. The research question developed for this study is: Are there position-specific differences in the morphological characteristics of South African sub-elite female soccer players? Hence, the primary aim of this article was to examine if there are position-specific differences in the morphological characteristics of South African sub-elite female soccer players. A secondary aim was to utilise the morphological characteristics of South African sub-elite female soccer players to establish the foundation for a database designed to create normative standards for this level of female soccer players. The hypothesis for the main aim of the study is that the morphological profile of South African sub-elite female soccer players will differ according to playing position. More research is required in future for the development of female soccer in South Africa.

## **METHODS**

### **Study design**

The study made use of a quantitative research method and cross-sectional design. A demographics questionnaire and an anthropometric datasheet were used to gather information.

### **Participants**

The study comprised 101 South African sub-elite female soccer players with a mean age of  $21.8 \pm 2.7$  years. A clear distinction between elite and sub-elite athletes is not defined in literature. For the purpose of this article, elite players are regarded as players competing on national level and higher divisions, while sub-elite level generally refer to players competing on club, college or university level. In line with previous studies on female soccer players (Haugen et al., 2012; Sporis et al., 2011; Vescovi et al., 2006) the players were divided into four positional groups, namely forwards, midfielders, defenders and goalkeepers. All the participants were regular soccer players competing in local club-level and student tournaments with an average of 7.5 years playing experience. The participants practiced on a regular basis (2–3 times per week). Measurements took place during the competition season. The study was approved by the Health Research Ethics Committee (NWU-00055-15-S1) of the university where the research was conducted. Research was conducted according to the Declaration of Helsinki. Participation in the study was voluntary and participants could withdraw from the study at any time and without prejudice. Prior to the start of the study, the participants were fully informed of the purpose and experimental procedures and an explanation of the potential risks and benefits of the study were given. Each player received a participant number in order to ensure anonymity.

### **Procedures**

#### ***Demographics questionnaire***

Written informed consent was obtained from all the players before commencement of the assessment procedures. The players had to submit the completed informed consent form on the day of testing if they wished to participate in the study. A questionnaire (see Appendix C), which made use of both open ended questions and a list of answers to select from, was administered before the testing procedures to collect the players' demographic and personal information

regarding name, age, ethnicity, exercise habits, playing position, years of participation and competing level.

### ***Anthropometric measurements***

Anthropometric measurements were taken according to the standard procedures of the International Society for the Advancement of Kinanthropometry (Stewart, Marfell-Jones, Olds, & de Ridder, 2011). Measurements included: (i) stature measured in centimeters to the nearest 0.1 cm using a Harpenden Portable Stadiometer (Holtain Limited, UK) with the player standing upright and the player's head in the Frankfort plane; (ii) body mass measured in kilograms to the nearest 0.1 kg using a portable electronic scale (Beurer Ps07 Electronic Scale, Ulm, Germany) with the participants wearing minimal clothing (such as shorts and a crop top) and no shoes; (iii) skinfolds of the triceps, subscapular, supraspinal, abdominal, frontal thigh and medial calf measured with a Harpenden Skinfold Caliper (Holtain Limited, UK) to the nearest 0.2 mm with a constant pressure of 10 g/mm<sup>2</sup>; (iv) breadths of the humerus, wrist, femur and ankle measured with a Holtain Bicondylar Caliper (Holtain Limited, UK) to the nearest 0.1 mm; (v) girth measurements for relaxed arm, flexed arm, waist, gluteus and mid-thigh taken with a Lufkin metal tape (Cooper Industries, USA) to the nearest 0.1 cm; and (vi) skeletal lengths of the upper arm, lower arm, hand and foot measured with a Rosscraft segmometer (Rosscraft Innovations Incorporated, Canada) to the nearest 0.1 cm. All anthropometric measurements were taken by the same two Level 2 ISAK-certified anthropometrists twice on the right-hand side of the body. The means of these measurements were used in the statistical analysis. Body fat percentage was calculated according to previously developed equations (Withers et al., 1987). Muscle and skeletal mass were calculated according to predetermined formulas (Lee et al., 2000). Somatotype was calculated using an established formula (Carter & Heath, 1990). Arm, mid-thigh and calf girths were corrected with the different skinfolds at these sites by applying the following formula: Corrected arm girth = Girth – (3.1416 x (triceps skinfold/10)); Corrected thigh girth = Girth – (3.1416 x (thigh skinfold/10)); Corrected calf girth = Girth – (3.1416 x (calf skinfold/10)). Corrected girths were used because they serve as better indicators of musculoskeletal size at each site (Martin, Spenst, Drinkwater, & Clarys, 1990). The technical error of measurement was calculated by applying a previously established formula (Pederson & Gore, 1996). A value of 1.80% (1.75 mm) was revealed for all skinfold measurements, 0.62% (0.16 cm) for all breadth

measurements, 0.01% (0.02 cm) for all girth measurements and 0.87% (0.19 cm) for all length measurements.

### Statistical analysis

The Statistical Package for Social Science (IBM SPSS Statistics 24) was used for statistical analysis. Descriptive statistics were calculated and used to describe the morphological characteristics of the players. The statistics were reported as mean  $\pm$  standard deviation (SD). One-way analysis of variance (ANOVA) was applied to test equality of means among the four playing positions in terms of morphological characteristics. Scheffe's *F* test was also used for multiple comparisons between groups. Tukey's post hoc test was used to quantify significant differences between playing positions for each variable. Effect size was used to compare differences in standardised effects between playing positions. Magnitudes of standardised effects were assessed as: 0–0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large, and >2.0 very large (Batterham & Hopkins, 2006). The level of statistical significance was set at  $p \leq 0.05$ .

### RESULTS

Descriptive statistics of the morphological characteristics for the total group and differences according to specific playing positions are presented in Table 1 and Table 2. The players had a mean standing height and mass of 160.0 cm and 57.1 kg respectively. The *F* values indicated that differences ( $p \leq 0.05$ ) existed among the positional groups in terms of means calculated for standing height, body mass and skinfold of the triceps and supraspinale. The highest mean results were recorded among goalkeepers. Goalkeepers differed with a moderate effect (ES: 0.7) and forwards differed with a small effect (ES: 0.3) in standing height with midfielders and defenders. With regard to body mass, goalkeepers differed with a moderate effect (ES: 0.9–1.1) from all three outfield playing positions, who only differed with trivial to small effect (ES: 0.1–0.3) from one another. Small to moderate (ES: 0.5–0.6) differences in the skinfold measurements of the triceps and supraspinale were observed between the goalkeepers and the outfield playing positions. Differences ( $p \leq 0.05$ ) between playing positions were also evident in the breadth measurements of the wrist (ES: 0.0–0.1, trivial effect) and femur (ES: 0.1–0.3, trivial to small effect), the girth measurements of the relaxed arm (ES: 0.0–0.5, trivial to small effect), flexed arm (ES: 0.1–0.5, trivial to small effect), waist (ES: 0.0–0.8, trivial to moderate effect), gluteal (ES: 0.0–0.8, trivial to moderate effect) and calf (ES: 0.0–0.5, trivial to small effect) and the length measurements of the acromiale-radiale (ES: 0.0–0.3, trivial to small effect), radiale-styilion (ES: 0.1–0.6, trivial to moderate effect), midstyilion-dactyilion (ES: 0.0–0.3, trivial to small

effect) and the foot (ES: 0.1–0.4, trivial to small effect). Again, goalkeepers on average had the largest breadth (ES: 0.1–0.3) and girth (ES: 0.5–0.8) and the longest length (ES: 0.3–0.6) measurements in comparison to the other positional groups.

Descriptive statistics for body composition characteristics and comparisons between playing positions are presented in Table 3. The sum of the six skinfolds in the total group was 97.5 mm. Significant differences ( $p \leq 0.05$ ) among the positional groups were only found for fat mass (kg) (ES: 0.0–0.6, trivial to moderate effect), muscle mass (kg) (ES: 0.1–0.6, trivial to moderate effect) and skeletal mass (kg) (ES: 0.0–0.3, trivial to small effect), with larger (ES: 0.3–0.6,  $p \leq 0.05$ ) results measured among the goalkeepers in comparison to the other positional groups. Midfielders showed the smallest average measurements for fat mass, muscle mass and skeletal mass. Midfielders also had a lower BF% and a higher muscle mass percentage than players in other positions. Forwards, midfielders and defenders had a similar skeletal mass percentage value.

**Table 1:** Age, stature and body mass of sub-elite female soccer players by playing position (mean  $\pm$  SD)

Variables	Total (n = 101)	FW (n = 25)	MF (n = 33)	DF (n = 34)	GK (n = 9)	F value	p
Chronological age (years)	21.8 $\pm$ 2.7	21.3 $\pm$ 2.3	21.7 $\pm$ 2.4	22.6 $\pm$ 3.0	20.6 $\pm$ 2.6	2.0	0.120
Body stature (cm)	160.0 $\pm$ 6.8	160.9 $\pm$ 5.7	158.7 $\pm$ 6.1 <sup>a,†</sup>	159.1 $\pm$ 6.9 <sup>b,¶</sup>	166.2 $\pm$ 8.4 <sup>a,b,†,¶</sup>	3.5	0.018
Body mass (kg)	57.1 $\pm$ 9.1	56.3 $\pm$ 8.4 <sup>a,†</sup>	55.0 $\pm$ 8.4 <sup>b,¶,*</sup>	57.4 $\pm$ 9.9 <sup>c,‡</sup>	66.5 $\pm$ 5.1 <sup>a,b,c,†,¶,‡</sup>	4.2	0.008

Note: SD: Standard Deviation; F: Variance of the group means; FW: Forwards; MF: Midfielders; DF: Defenders; GK: Goalkeepers.

Corresponding letters indicate significant differences at  $p \leq 0.05$ . \* Differs significantly from goalkeepers at  $p \leq 0.01$

Effect size: Corresponding symbols indicate a moderate or larger effect size

**Table 2: Descriptive morphology of sub-elite female soccer players by playing position (mean  $\pm$  SD)**

Variables	Total (n = 101)	FW (n = 25)	MF (n = 33)	DF (n = 34)	GK (n = 9)	F value	p
<b>Skinfolds (mm)</b>							
Tricep	16.0 $\pm$ 5.3	15.1 $\pm$ 4.7 <sup>a,†</sup>	15.5 $\pm$ 4.9 <sup>†</sup>	15.9 $\pm$ 5.7	20.5 $\pm$ 5.8 <sup>a,†,††</sup>	2.7	0.052
Subscapular	11.4 $\pm$ 4.7	11.4 $\pm$ 4.5	10.9 $\pm$ 3.9	10.9 $\pm$ 3.4	14.6 $\pm$ 9.4	1.7	0.169
Supraspinale	10.3 $\pm$ 5.3	9.6 $\pm$ 4.1 <sup>a,†</sup>	9.3 $\pm$ 4.4 <sup>b,††</sup>	10.7 $\pm$ 4.5	15.0 $\pm$ 10.4 <sup>a,b,†,††</sup>	3.1	0.030
Abdominal	19.2 $\pm$ 8.3	18.8 $\pm$ 8.0	17.8 $\pm$ 8.4	19.3 $\pm$ 7.7	24.2 $\pm$ 9.9	1.4	0.233
Front thigh	24.9 $\pm$ 10.2	24.1 $\pm$ 8.9	23.8 $\pm$ 9.7	24.7 $\pm$ 11.3	32.4 $\pm$ 9.9	1.8	0.145
Medial calf	15.7 $\pm$ 6.1	15.9 $\pm$ 5.1	15.1 $\pm$ 7.2	15.4 $\pm$ 5.9	18.9 $\pm$ 5.3	0.9	0.421
<b>Breadths (cm)</b>							
Humerus	6.1 $\pm$ 0.3	6.0 $\pm$ 0.3	6.1 $\pm$ 0.3	6.2 $\pm$ 0.4	6.3 $\pm$ 0.5	2.2	0.097
Wrist	5.1 $\pm$ 0.3	5.1 $\pm$ 0.3	5.1 $\pm$ 0.2 <sup>a</sup>	5.1 $\pm$ 0.3 <sup>b</sup>	5.3 $\pm$ 0.3 <sup>a,b</sup>	2.8	0.044
Femur	8.9 $\pm$ 0.5	8.9 $\pm$ 0.4 <sup>a</sup>	8.7 $\pm$ 0.4 <sup>b,*</sup>	9.0 $\pm$ 0.6	9.4 $\pm$ 0.5 <sup>a,b</sup>	4.7	0.004
Ankle	6.5 $\pm$ 0.4	6.4 $\pm$ 0.4	6.4 $\pm$ 0.3	6.6 $\pm$ 0.4	6.7 $\pm$ 0.3	3.0	0.034
<b>Girths (cm)</b>							
Relaxed arm	24.9 $\pm$ 2.6	24.5 $\pm$ 2.6 <sup>a</sup>	24.5 $\pm$ 2.4 <sup>b</sup>	25.0 $\pm$ 2.5	27.4 $\pm$ 2.1 <sup>a,b</sup>	3.6	0.017
Flexed arm	26.4 $\pm$ 2.4	26.1 $\pm$ 2.5 <sup>a</sup>	25.9 $\pm$ 2.1 <sup>b,*</sup>	26.4 $\pm$ 2.4 <sup>c</sup>	28.7 $\pm$ 1.9 <sup>a,b,c</sup>	3.8	0.012
Waist	68.0 $\pm$ 5.9	67.7 $\pm$ 6.5 <sup>a,†</sup>	66.5 $\pm$ 5.3 <sup>b,††,*</sup>	68.0 $\pm$ 5.5 <sup>c,‡</sup>	73.9 $\pm$ 5.4 <sup>a,b,c,†,††,‡</sup>	4.0	0.010
Gluteal	93.4 $\pm$ 6.7	92.4 $\pm$ 6.7 <sup>a,†</sup>	92.8 $\pm$ 6.4 <sup>b,††</sup>	93.1 $\pm$ 6.7 <sup>c,‡</sup>	99.9 $\pm$ 4.4 <sup>a,b,c,†,††,‡</sup>	3.3	0.022
Mid-thigh	51.2 $\pm$ 4.6	50.3 $\pm$ 4.9	50.7 $\pm$ 3.9	51.6 $\pm$ 4.9	54.6 $\pm$ 4.0	2.3	0.085
Calf	32.9 $\pm$ 2.6	32.6 $\pm$ 2.1 <sup>a</sup>	32.4 $\pm$ 2.2 <sup>b,*</sup>	32.9 $\pm$ 3.0 <sup>c</sup>	35.5 $\pm$ 2.0 <sup>a,b,c</sup>	3.7	0.014
<b>Lengths (cm)</b>							
Acromiale-radiale	30.7 $\pm$ 1.6	31.0 $\pm$ 1.3	30.4 $\pm$ 1.4 <sup>a</sup>	30.5 $\pm$ 1.7	32.0 $\pm$ 1.9 <sup>a</sup>	3.0	0.032
Radiale-styilion	24.2 $\pm$ 1.5	24.3 $\pm$ 1.2 <sup>a*</sup>	23.8 $\pm$ 1.4 <sup>b,†,*</sup>	24.1 $\pm$ 1.3 <sup>c,*</sup>	26.3 $\pm$ 1.6 <sup>a,b,c,†</sup>	8.6	0.000
Midstyilion-dactyilion	18.5 $\pm$ 1.0	18.5 $\pm$ 1.0	18.3 $\pm$ 1.0 <sup>a,*</sup>	18.3 $\pm$ 0.9 <sup>b,*</sup>	19.5 $\pm$ 1.2 <sup>a,b</sup>	4.2	0.008
Foot	24.4 $\pm$ 1.6	24.6 $\pm$ 1.0	24.3 $\pm$ 1.1	24.1 $\pm$ 2.2 <sup>a</sup>	25.8 $\pm$ 0.7 <sup>a</sup>	3.0	0.033

Note: SD: Standard Deviation; F: Variance of the group means; FW: Forwards; MF: Midfielders; DF: Defenders; GK: Goalkeepers.

Corresponding letters indicate significant differences at  $p \leq 0.05$ . \* Differs significantly from goalkeepers at  $p \leq 0.01$

Effect size: Corresponding symbols indicate a moderate or larger effect size

Somatotype did not differ according to playing positions, and an average balanced endomorphic somatotype of 4.0–2.4–2.1 was recorded for the total group as displayed in Table 3. All positional groups had average endomorphic values. While the forwards and midfielders presented a balanced endomorph somatotype, the defenders and goalkeepers showed an average mesomorphic-endomorph somatotype. Mesomorphic values were low for forwards and midfielders and average for defenders and goalkeepers. All positional groups had low ectomorphic values. The somatotype chart (Figure 1) shows the location of the somatopoints of the mean somatotype for the total group and each playing position.

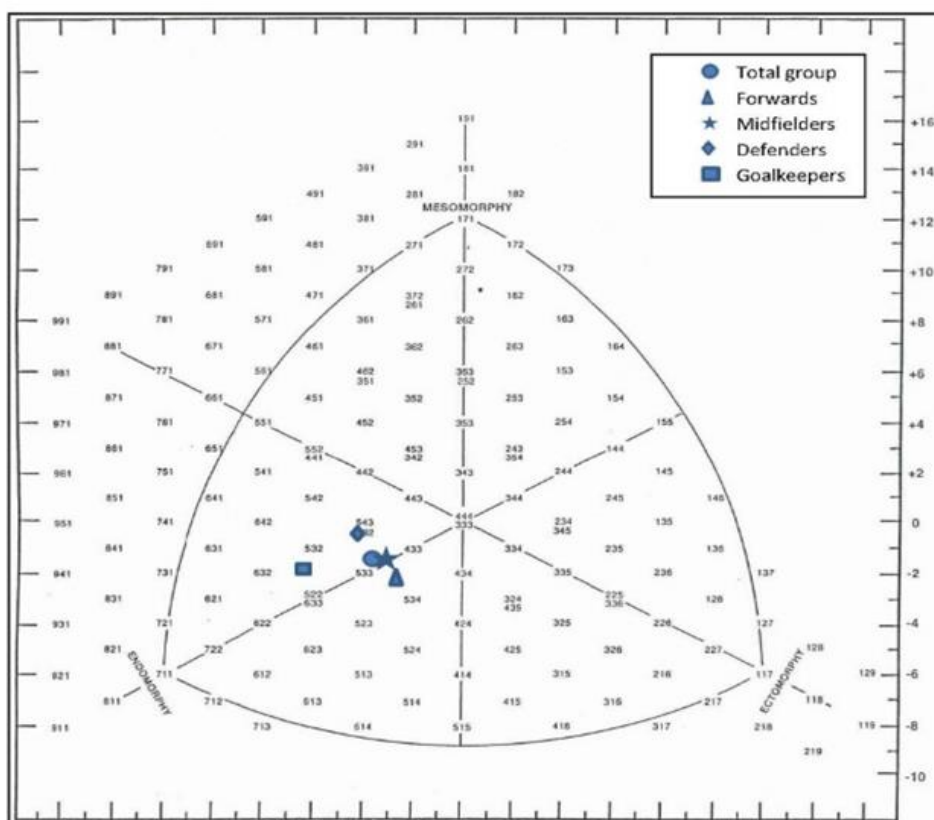


Figure 1: Somatotype distribution of sub-elite female soccer players by playing position. An average balanced-endomorph somatotype is evident among all the playing positions.

**Table 3: Body composition characteristics of sub-elite female soccer players by positional group (mean  $\pm$  SD)**

Variables	Total ( <i>n</i> = 101)	FW ( <i>n</i> = 25)	MF ( <i>n</i> = 33)	DF ( <i>n</i> = 34)	GK ( <i>n</i> = 9)	<i>F</i> value	<i>p</i>
Sum of 6 skinfolds (mm)	97.5 $\pm$ 35.8	94.9 $\pm$ 31.7	92.3 $\pm$ 35.4	96.9 $\pm$ 34.2	125.6 $\pm$ 45.9	2.2	0.092
Fat (kg)	12.2 $\pm$ 5.2	20.4 $\pm$ 5.1 <sup>a</sup>	20.0 $\pm$ 5.7 <sup>b,†</sup>	20.6 $\pm$ 5.5 <sup>c</sup>	25.4 $\pm$ 7.2 <sup>a,b,c,†</sup>	2.3	0.081
Fat %	20.8 $\pm$ 5.7	11.8 $\pm$ 4.6	11.3 $\pm$ 4.8	12.2 $\pm$ 5.1	17.2 $\pm$ 6.2	2.4	0.022
Muscle mass (kg)	21.3 $\pm$ 2.1	21.1 $\pm$ 1.9 <sup>a,*</sup>	20.8 $\pm$ 1.9 <sup>b,†,*</sup>	21.3 $\pm$ 2.2 <sup>c,*</sup>	23.7 $\pm$ 1.0 <sup>a,b,c,†</sup>	5.2	0.002
Muscle mass %	37.7 $\pm$ 2.7	37.9 $\pm$ 2.4	38.2 $\pm$ 2.6	37.6 $\pm$ 2.8	35.7 $\pm$ 2.0	2.1	0.107
Skeletal mass (kg)	6.8 $\pm$ 0.9	6.8 $\pm$ 0.7 <sup>a</sup>	6.6 $\pm$ 0.7 <sup>b*</sup>	6.9 $\pm$ 1.0 <sup>c</sup>	7.7 $\pm$ 1.0 <sup>a,b,c</sup>	4.3	0.007
Skeletal mass %	12.1 $\pm$ 1.2	12.1 $\pm$ 1.4	12.1 $\pm$ 1.2	12.1 $\pm$ 1.1	11.6 $\pm$ 1.2	0.5	0.693
Endomorphy	4.0 $\pm$ 1.3	3.8 $\pm$ 1.2	3.8 $\pm$ 1.2	4.0 $\pm$ 1.3	4.9 $\pm$ 1.8	1.8	0.147
Mesomorphy	2.4 $\pm$ 0.9	2.0 $\pm$ 0.9	2.3 $\pm$ 0.7	2.7 $\pm$ 1.0	2.5 $\pm$ 1.2	1.8	0.145
Ectomorphy	2.1 $\pm$ 1.2	2.4 $\pm$ 1.4	2.1 $\pm$ 1.0	1.9 $\pm$ 1.3	1.7 $\pm$ 1.3	1.2	0.374

Note: SD: Standard Deviation; *F*: Variance of the group means; FW: Forwards; MF: Midfielders; DF: Defenders; GK: Goalkeepers

Corresponding letters indicate significant differences at  $p \leq 0.05$ . \* Differs significantly from goalkeepers at  $p \leq 0.01$

Effect size: Corresponding symbols indicate a moderate or larger effect size

## **DISCUSSION**

The primary aim of this study was to examine if there are position-specific differences in the morphological characteristics of South African sub-elite female soccer players. The secondary aim was to utilise the morphological characteristics of South African sub-elite female soccer players to establish the foundation for a database designed to create normative standards for this level of female soccer players. Adding to the uniqueness of this study is the large sample size in comparison to most other studies on female soccer players, cited in this paper. The main finding of this study was that the players showed an average mesomorphic-endomorphic somatotype for sub-elite female soccer players. Furthermore, the study revealed positional differences in the players' morphological characteristics.

Standing height and body mass values of the current study were found to be comparable with values reported for elite Spanish (Sedano et al., 2009) and sub-elite Japanese (Hasegawa & Kuzuhara, 2015) female soccer players. However, the majority of previous research on female soccer players reported considerably higher values for standing height and body mass among both sub-elite (Nikolaidis, 2014; Vescovi et al., 2006) and elite female players (Milanovic et al., 2012; Sporis et al., 2011). Standing height is regarded as a decisive factor in the selection process in soccer and is considered favorable for goalkeepers when defending a goal (Sporis et al., 2007). In agreement with other studies (Haugen, Tonnessen, Hem, Leirstein, & Seiler, 2014; Milanovic et al., 2012; Vescovi et al., 2006), goalkeepers were taller than the outfield players, with results being significant ( $p < 0.02$ ) in comparison to midfielders and defenders. None of the outfield playing positions differed ( $p > 0.05$ ) from one another in terms of body height. However, similar to previous studies (Dillern et al., 2012; Sedano et al., 2009; Sporis et al., 2007; Vescovi et al., 2006), on average, midfielders were the shortest players. The standing height of forwards and defenders were alike. However, it would be expected that the height of forwards would be similar to defenders, taking into account the direct duels when jumping in front of the goal (Matković et al., 2003). Therefore, a particular height may orient a player towards a specific positional role (Dey et al., 2010) and may be a noteworthy factor for tactical success (Hazir, 2010). The standing height values were partly accompanied by the total body mass, leading to the conclusion that goalkeepers were on average the heaviest and midfielders were the lightest, thus supporting previous findings in literature (Haugen et al., 2012; Sporis et al., 2007). Significant results were found in the comparison of the goalkeepers to the forwards ( $p = 0.02$ ), midfielders ( $p = 0.004$ ) and defenders ( $p = 0.03$ ). The heavier body mass often observed in goalkeepers is presumably due

to the fact that endurance is less important for goalkeepers than for outfield players (Rogan et al., 2011).

The influence of body composition on performance can extend much further than standing height (Hazir, 2010). In this regard, various skeletal measurements should also be considered. Skeletal breadth, girth, length and skinfold measurements of the players in the current study were comparable with other female soccer players on sub-elite and elite level, although available literature is very limited for all levels of participation (Adhikari & Nugent, 2014; Jelaska et al., 2015; Mujika, Santisteban, Impellizzeri, & Castagna, 2009; Sedano et al., 2009; Sporis et al., 2007). Results from the current study were either similar (thigh girth and humerus, wrist, femur and ankle breadth) or lower (relaxed arm, flexed arm and waist and calf girth) than previous reports (Can, Yilmaz, & Erden, 2004; Jelaska et al., 2015; Sporis et al., 2007). Upper limb skeletal length for players were longer than those in previous reports but cannot be directly related since this study made use of three measurements (mean acromiale-radiale, mean radiale-stylion and mean midstylion-dactylion) in comparison to the single measurement used for arm length in previous reports (Can et al., 2004; Jelaska et al., 2015; Sporis et al., 2007).

Differences ( $p \leq 0.05$ ) were found between playing positions in the mean breadth measurements of the wrist, femur and ankle and the mean girth measurements of the relaxed arm, flexed arm, waist, gluteus and medial calf. Goalkeepers had larger ( $p \leq 0.05$ ) wrist breadth measurements compared to midfielders and defenders and larger femur breadth measurements compared to forwards ( $p = 0.02$ ) and midfielders ( $p = 0.003$ ). A previous study on female players also reported the largest breadth measurements among goalkeepers (Sporis et al., 2007). The forwards had the smallest humerus and ankle breadth measurements, followed by the midfielders who again had the smallest wrist and femur breadth measurements. In terms of girth measurements, differences ( $p \leq 0.05$ ) were found between goalkeepers and the other three positional groups, with the largest measurements being noted among goalkeepers. Midfielders possessed the smallest mean results for the majority of girths measured, which concurs with previous studies (Sporis et al., 2007). Due to limited data being available on female players, the current study can confirm that the results of the female players with regard to breadth and girth measurements relating to specific playing positions were similar to results reported for male players, with breadth and girth measurements being smaller for female players compared to males (Matković et al., 2003; Rogan et al., 2011).

Players in different positions further varied ( $p \leq 0.05$ ) in terms of the mean length measurements. Goalkeepers had longer ( $p \leq 0.05$ ) acromiale-radiale length measurements than midfielders and

defenders and longer ( $p \leq 0.01$ ) radiale-stylion length measurements compared to all outfield positions, thus agreeing with previous reports (Sporis et al., 2007). This particular body type contributes to the self-confidence of goalkeepers in performing their tasks of covering the broad area between the goalposts (Matković et al., 2003). Once again, the midfielders had the shortest arm and hand lengths, as has been found previously (Sporis et al., 2007). Furthermore, goalkeepers had larger hands ( $p \leq 0.01$ ) and longer feet ( $p \leq 0.05$ ) than midfielders and defenders. In considering standing height and body mass values of the different playing positions, it was not unexpected that the shorter and lighter midfielders generally possessed the smallest skeletal breadth, girth and length measurements. In addition, larger values were found among the taller and heavier forwards and defenders and ultimately, the largest measurements accompanying the tallest and heaviest values were established among the goalkeepers.

Skinfold and body fat measurements are also contributing factors for determining a player's body composition. Although a certain amount of body fat is important for the maintenance of body metabolism, it is believed that excess adiposity negatively influences soccer performance (Anwar & Noohu, 2016; Slimani, Znazen, Hammami, & Bragazzi, 2017). The sum of the skinfolds can be used to determine adiposity and to provide detail regarding local fat depots and fat distribution in the body (Garrido-Chamorro, Sirvent-Belando, González-Lorenzo, Blasco-Lafarga, & Roche, 2012). The average of the sum of six skinfolds was considerably higher than that previously reported (Mujika et al., 2009) for elite female players in terms of similar skinfold sites measured and was more in agreement with the values reported for junior female players. No difference was found between the different playing positions. However, the midfielders had the lowest total sum of six skinfolds, followed by the forwards and defenders, with the goalkeepers demonstrating the largest value. The body fat mass and mean BF% of the players lay within the ranges previously reported for female players (Hasegawa & Kuzuhara, 2015; Nikolaidis, 2014; Sedano et al., 2009). Higher muscle mass values than found in this study have been reported for sub-elite and elite Spanish female players (Sedano et al., 2009). Differences were noted between the different playing positions concerning the muscle mass ( $p < 0.01$ ), skeletal mass ( $p < 0.01$ ) and fat mass ( $p < 0.05$ ) values when goalkeepers were compared to the outfield positions. No differences were observed when the outfield positions were compared with one another. The highest mean muscle, skeletal and fat mass values were measured among goalkeepers, while the smallest values were measured among midfielders. The higher BF% values found among goalkeepers could be attributed to their specific positional requirements of being steadier throughout the game and less mobile. This is in comparison to other playing positions that require the players to be more manoeuvrable and to cover a greater distance throughout a match, which could explain the lower BF% measured among them. Forwards and defenders, however, had similar BF% values

compared to midfielders, indicating that BF% was not a distinguishing factor among outfield positions. This agrees with results previously reported for elite Japanese female players (Hasegawa & Kuzuhara, 2015) and elite and sub-elite Spanish (Sedano et al., 2009) female players.

Finally, somatotype is a useful unit of measure that highlights the overall health status of individuals (Ochoa Martínez et al., 2014). In soccer, the mesomorphic component is an important factor for strength together with a prevalence of ectomorphic components (Adhikari & Nugent, 2014). Therefore, an ectomorphic mesomorph body type is more desirable for speed and endurance with strong muscle power (Adhikari & Nugent, 2014). Although there is a shortage of studies describing the somatotype of female soccer players, the majority reported an endomorphic mesomorph body type (Adhikari & Nugent, 2014; Can et al., 2004; Withers, Whittingham, Norton, & Dutton, 1987), with one study reporting a mesomorphic endomorph body type (Nikolaidis, 2014). The players in the present study demonstrated a balanced endomorph body type. This can be translated into an average value for the endomorphic component and low values for both the mesomorphic and ectomorphic components, indicating that on average, the players had a shorter body type and less muscle characteristics compared to previously reported results. None of the positional groups differed in somatotype characteristics. Defenders and goalkeepers showed more endomorphic and mesomorphic components, while forwards demonstrated the highest ectomorphic component of all the positional groups and midfielders showed the lowest endomorphic component. Comparisons to other studies regarding somatotype characteristics according to playing position could, however, not be made since such analyses have not been conducted previously.

It is, however, notable that midfielders who possessed the lowest endomorphic values also had the lowest BF%, while goalkeepers and defenders, who had the highest endomorphic values, had higher BF% values. The higher endomorphy component observed in goalkeepers could be the result of less intensive training, work-load profile in matches and energy expenditure. Higher level players tend to be more mesomorphic and less endomorphic and ectomorphic than players of a lower standard (Hazir, 2010), which could partly explain the differences observed between the current study on sub-elite players and earlier studies on elite players. Regular training can lead to a general increase in the mesomorphic component and a decrease in the endomorphic component (Can et al., 2004). A change in BF% could change the body type of the players in the present study into an ectomorphic mesomorph body type, which could have a positive influence on performance.

## **PRACTICAL APPLICATIONS AND LIMITATIONS**

This study provided valuable information concerning the morphological profile of sub-elite female soccer players in accordance with playing position, although several limitations of the study should be considered, along with recommendations for future researchers who wish to further explore this area of study. The participants in this study were not randomly selected according to the population representative of players competing on sub-elite level in South Africa. Future studies should include players participating on sub-elite level which would be representative of the entire population in the country.

The results of the present study show heterogeneity among playing positions and suggest that goalkeepers differ in morphological characteristics compared to outfield players. The results support previous research in that players in defensive positions tend to be among the taller players, which could be advantageous in performing actions such as jumping to gain possession of the ball and defending the goal. Midfielders are likely to be the shortest and lightest players in a team, lending them the advantage of being more manoeuvrable across the field. The inclination of the endomorphic component may be viewed as an indication of undertraining. Coaches and their players should remember that excessive body fat is an important factor influencing performance negatively. The control of body fat content and the regular undertaking of somatotype assessment are, therefore, essential. Each positional role are characterized by a different profile, highlighting the importance of dedicating certain training sessions to training specific to each position. Quantification and comparison of morphological profiles across playing positions can provide coaches and conditioning specialists with a better understanding of the specific demands of certain positions. This may consequently enhance training sessions through the prescription of optimal position-specific training programmes and lead to better performance in matches. Finally, because an aim of this study was to establish normative data within an area characterized by a rarity of information, this study can be regarded as a important contribution to the field for future reference and comparisons.

## **ACKNOWLEDGEMENTS**

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## **CHAPTER 4**

# **THE EFFECT OF EXERCISE-INDUCED FATIGUE ON THE TECHNICAL SKILL PERFORMANCE OF SUB-ELITE FEMALE SOCCER PLAYERS**

This article will be submitted for publication in the Journal of Sports Science and Medicine. The article is included herewith in accordance with the guidelines for authors of this esteemed journal (included as Appendix E). However, to provide a neat and well-rounded final product for this thesis, the article has been edited to represent an actual published article as it would appear in this particular journal. This does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from that used in the other chapters of this thesis.

## THE EFFECT OF EXERCISE-INDUCED FATIGUE ON THE TECHNICAL SKILL PERFORMANCE OF SUB-ELITE FEMALE SOCCER PLAYERS

Submission type: Research article

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## Abstract

**Objectives:** To evaluate the effect of aerobic and anaerobic fatigue on the technical skill performance of sub-elite female soccer players, and to determine the aerobic and anaerobic fitness characteristics of sub-elite female soccer players. **Methods:** Forty-eight female soccer players participated in the study. Players completed the Loughborough Soccer Passing Test (LSPT) before and directly following the execution of an anaerobic repeated sprint ability (RSA) test and an aerobic Yo-Yo Intermittent Recovery Level 1 (Yo-Yo IR1) test on two consecutive days. Maximal heart rate and blood lactate concentration were obtained following the fatiguing exercises. **Results:** Players covered a mean distance of 560 m in the Yo-Yo IR1 and 614 m in the RSA test. Maximal heart rate values of 190 bpm and 186 bpm were recorded following the aerobic and anaerobic fitness tests respectively. A decline in the LSPT was found in terms of passing, penalty and total time following both fatiguing exercises, and displayed small to moderate effect sizes. A significant ( $p < 0.001$ ) increase in penalty time (32.6%) and total performance time (10.1%) was recorded following the Yo-Yo IR1. Penalty time (20.4%) and total performance time (8.5%) also increased following the RSA test. **Conclusions:** Physical fatigue has a detrimental effect on short-passing ability, with aerobic fatigue influencing passing accuracy more than anaerobic fatigue, resulting in a larger decline in technical skill performance. Therefore, the fatigue-related decline in technical performance is associated with the fitness level of a player.

**Keywords:** aerobic fatigue, anaerobic fatigue, fitness, Loughborough Soccer Passing Test, skill performance

## Introduction

The increase in attention devoted to scientific research in female soccer is evidence of the rise in popularity of this sport among females worldwide (Datson *et al.*, 2014). Consequently, the profiles of female players and their development towards becoming elite performers are topics of decisive interest in the soccer milieu (Dillern *et al.*, 2012). Recent studies have shown a decline in physical performance during matches (Hewitt *et al.*, 2014; Vescovi & Favero, 2014). For this reason, the evaluation of a player's aerobic and anaerobic capacity is important since these variables may determine play a role in the match outcome (Bangsbo *et al.*, 2008)

Female elite players cover a total distance of approximately 8–11 km during matches (Mohr *et al.*, 2008; Hewitt *et al.*, 2014; Vescovi & Favero, 2014; Trewin *et al.*, 2018). Therefore, a high level of aerobic fitness is required (Milanovic *et al.*, 2012). The specificity and practicality of the Yo-Yo Intermittent Recovery (Yo-Yo IR) tests for the assessment of aerobic fitness have resulted in them being widely applied in many team sports and rapidly becoming one of the most intensively studied fitness tests in sport science (Bangsbo *et al.*, 2008). Another characteristic of soccer players is the ability to perform numerous short-duration sprints (< 10 s) interspersed with short periods of rest (< 30 s) or low- to moderate-intensity activity (Bishop & Spencer, 2004). This is known as repeated-sprint ability (RSA). Repeated-sprint ability is commonly accepted as a critical component of high-intensity intermittent sports such as soccer (Gabbett, 2010). Despite the importance of RSA, more research is required in female soccer for the establishment of normative data; this is partly due to the diverse range of testing protocols available.

Soccer further requires the simultaneous performance of technical skills throughout high-intensity intermittent exercise (Russell *et al.*, 2010). The contribution of anaerobic metabolism to energy provision is essential during a soccer match since skillful actions are dependent on quick and powerful movements (Ali & Williams, 2009). Technical performance is also believed to be influenced by aerobic fitness, particularly during the latter stages of a match (Russell & Kingsley, 2011). The impact of fatigue on technical skill performance has been explored quite well in male soccer players (Rampinini *et al.*, 2008; Rampinini *et al.*, 2009; Stone & Oliver, 2009; Russell *et al.*, 2011). Even though it is evident that match-related fatigue has a negative effect on physical performance, limited research has examined the effect of fatigue on the quality of short-passing ability (Lyons *et al.*, 2006; Rampinini *et al.*, 2008). The deterioration of short-passing skills may be related to fatigue accumulated throughout a match and to the acute fatigue that is secondary to high-intensity phases of short duration (Rampinini *et al.*, 2008). Limited experimental research is available in this area due to the difficulty in replicating the complex nature of soccer skills within

a laboratory context (Ali, 2011). However, the Loughborough Soccer Passing Test (LSPT) has previously been used to assess skill performance at regular intervals during exercise (Ali & Williams, 2009), which can be utilized for examining the effect of fatigue on skill performance (Ali, 2011). The LSPT is the first soccer skill test to be validated for female players and is recommended to evaluate the soccer skill performance of female players in research settings (Ali *et al.*, 2008).

Research has clarified the physical fitness characteristics of female soccer players in European and American countries (Vescovi *et al.*, 2006; Dillern *et al.*, 2012; Haugen *et al.*, 2014). To the authors' knowledge, no information exists on sub-elite female soccer players in Africa that describes and compares the effect of aerobic and anaerobic fatigue on technical-skill performance. The first aim of the study was to evaluate the effect of aerobic and anaerobic fatigue on the technical skill performance of sub-elite female soccer players. The secondary aim was to determine the aerobic and anaerobic fitness characteristics of sub-elite female soccer players.

## **Methods**

### **Subjects**

Forty-eight (n=48) South African sub-elite female soccer players (age:  $22.0 \pm 2.7$  years; height:  $158.9 \pm 5.8$  cm; body mass:  $55.5 \pm 8.1$  kg) representing two university teams participated in the study. The participants were purposefully selected and classified as sub-elite level players. All players were soccer players in local tournaments (consisting of formal league club matches and university tournaments) with an average of 7.5 years of playing experience. The players were assessed during the competitive season. Prior to the start of the study, the players were fully informed of the aims of the study and experimental procedures together with the potential risks and benefits. Written informed consent was obtained from all the players before commencement of the assessment procedures. Players were excluded if they were injured.

### **Study design**

The study made use of a quantitative research method through a descriptive and exploratory focus design. A demographic questionnaire and a physical performance datasheet were used to gather information. The study was approved by the Health Research Ethics Committee (NWU-00055-15-S1) of the university where the research was conducted. Research was conducted according to the Declaration of Helsinki. Each player received a participant number in order to ensure anonymity.

## Methodology

### **Aerobic capacity: Yo-Yo IR1**

The Yo-Yo IR1, as described previously (Bangsbo *et al.*, 2006), was used to evaluate the aerobic capacity of each player. Cones were used to mark three lines, 20 m and 5 m apart. A commercially available pre-recorded compact disc (CD) was played using a CD player. The players were required to run back and forth between the lines at given speeds controlled by the CD. Upon starting the test, the player stood behind the middle line, facing the last line, and began running 20 m when instructed by the CD. When signalled by the CD, the player turned and returned to the starting point. The player was required to touch the marked lines at either end of the 20 m with one foot when the signal beeped. After each 40 m, the player received a brief 10 sec active recovery period, during which the player had walk back and forth over a 5 m distance. The initial running speed was 10km/h, after which the speed progressively increased. If the line was not reached in time for a beep, a verbal warning was given. The test was terminated if the player failed to reach the line for two consecutive ends within the given time or if the player stopped voluntarily. The last level and number of successfully completed shuttles by each player were recorded for statistical analysis. Total distance covered during the test was recorded. The maximal oxygen consumption ( $\dot{V}O_{2max}$ ) of each player was estimated through a formula previously used for estimating  $\dot{V}O_{2max}$  from the Yo-Yo IR1 (Bangsbo *et al.*, 2008). A correlation ( $p < 0.05$ ) exist between the Yo-Yo IR1 and  $\dot{V}O_{2max}$  (Bangsbo *et al.*, 2008). Therefore,  $\dot{V}O_{2max}$  can be estimated for the Yo-Yo IR1 (Bangsbo *et al.*, 2008).

### **Anaerobic capacity: RSA test**

The RSA test was used according to a previously described method (Boddington *et al.*, 2001) to assess anaerobic fitness. Six cones were placed 5 m apart in a straight line to cover a total distance of 25 m. The player started the test on the first cone and, upon an auditory signal, sprinted 5 m to the second cone and returned back to the first cone. The player then sprinted 10 m to the third cone and back to the first cone, et cetera. The player continued sprinting back and forth until a period of 30 sec has elapsed. After the first bout, the player was given a 35 sec rest period before starting the second bout of the activity. The activity was repeated for six times (bouts). The players were instructed not to pace themselves but to perform with maximal effort throughout the test. The distance covered by each player was approximated to the nearest 2.5 m during each 30 s shuttle, and this was used to determine the average total distance covered. An analysis by Spencer *et al.* (2005) on different studies that assessed RSA concluded that a protocol

involving six to seven sprints may best represent an intense bout of RSA specific to field-based team sports during competition.

### **Heart rate and blood lactate monitoring**

The players were fitted with a Polar Heart Rate Transmitter Belt (Polar Electro, Kempele, Finland) before performing both the Yo-Yo IR1 and the RSA tests to measure the heart rate (HR) for each 5 s period while completing the fitness tests. Immediately after completion of the Yo-Yo IR1 test and the RSA test, a blood sample was collected from the fingertip of the left hand to determine blood lactate concentration. A portable analyzer (Lactate Pro, Arkray, Japan) was used to measure blood lactate concentration in mmol/L. The portable analyzer was calibrated before each blood sampling and used according to the manufacturer guidelines. The player's finger was cleaned with an alcohol swab before each measurement. The blood samples taken were only used to confirm that each player was fatigued from the fitness tests before commencement of the technical skills test. Blood sampling was purposefully done immediately following the aerobic and anaerobic activities due to the design of the study in which players need to progress to the technical skill assessment as soon as possible in order to evaluate if aerobic or anaerobic fatigue would influence technical skill performance negatively.

### **Loughborough Soccer Passing Test (LSPT)**

The LSPT was used to assess the multi-faceted aspects of soccer skills, including passing, dribbling, control and decision-making. Prior to the start of the study, the players were sufficiently familiarized with the LSPT protocol during a practice session in which the execution of the LSPT was explained and demonstrated to the players, and the players had opportunity to perform the test themselves. Figure 1 illustrates the layout of the LSPT. The performance score comprised three variables: time taken to complete the LSPT; penalty time accrued; and total performance time. The execution of the test and the awarded penalty time were in accordance with a previous study (Ali *et al.*, 2008). Four standard gymnasium benches were placed on a grass soccer field, marking a 12 x 9.5 m grid (to the inside of the benches). Four coloured (green, blue, red and white) pieces of cloth (0.6 x 0.3 m) were fixed to the middle of each bench, with a black coloured piece of cloth (0.1 x 0.15 m) fixed vertically in the middle of the target areas. Yellow tape was used to mark the inner (1 x 2.5 m) and outer (2.5 x 4 m) rectangles. The passing zone was the area between these lines. Coloured cones were used to distinguish the different zones. The player performed 16 passes against the coloured target areas as quickly as possible. Penalty time accrued for inaccurate passing and poor ball control. The order of passes (colour of next target) was called out by one investigator, while another investigator recorded the time taken and penalty

time accrued (the sum of which made up total performance time). The same pair of investigators was used to conduct the LSPTS in order to avoid inter-examiner variability. The next target was called out once the ball hit the target during the current pass. The order of passes were determined by one of the four trial orders randomly generated by the investigators, with each trial consisting of eight long passes (green and blue) and eight short passes (white and red). Passes had to be executed from within the passing area. Players were also informed that upon retrieval from the previous pass, the ball first had to cross two of the inner marked lines before the next pass could be attempted. The time was stopped when the last pass made contact with the target area. Penalty time was awarded for the following errors: missing bench completely or passing to wrong bench (5 s); missing target area (3 s); handling the ball (3 s); passing from outside of the designated area (2 s); ball touching any cone (2 s); every second taken over the allocated 43 s to complete the test (1 s). A deduction of 1 s was done from the total time if the ball hit the 10 cm black cloth in the middle of the target.

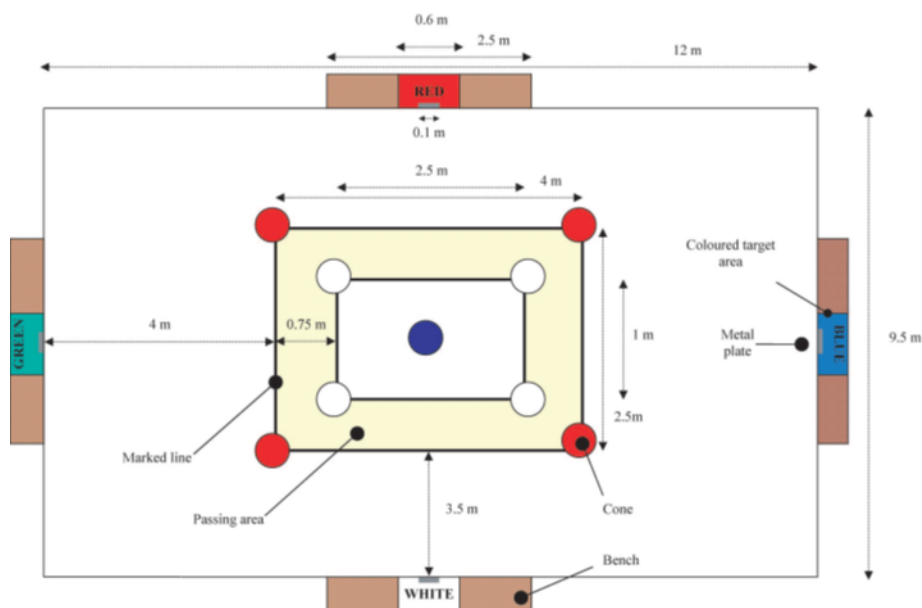


Figure 1: Schematic representation of the LSPTS (Ali *et al.*, 2008) (used by permission)

### Procedures

After the players had given written informed consent, they were required to complete a demographic and general information questionnaire. Testing was conducted over two consecutive days and players did not engage in normal training sessions between the two testing days. To avoid inter-examiner variability during the LSPTS, players were assessed one at a time

throughout all tests performed. Before testing commenced, the players engaged in a general warm-up of 15 min consisting of low-intensity aerobic activity followed by static and dynamic stretching. On the first day, each player performed the LSPT and progressed to the RSA test upon completion of the technical skills test. Immediately following the RSA test, blood sampling was carried out. Then without any rest, the player completed the LSPT. On the second day, each player performed the LSPT followed by the Yo-Yo IR1 test. Immediately following the Yo-Yo IR1 test, blood lactate measurements were done. Again, without any rest, the player then completed the LSPT. After completion of each fitness test, the player's maximal HR and rate of perceived exertion (RPE) were recorded. The Borg CR10 scale modified by Foster *et al.* (1996) was used as a guideline to record the players' perceived exertion during the tests (Impellizzeri *et al.*, 2004). The tests were performed on a grass soccer field with players wearing their soccer boots. Players were instructed not to engage in strenuous exercise for at least 48 hours before the testing.

### **Statistical analysis**

The Statistical Package for the Social Sciences (IBM SPSS Statistics 22) was used for statistical analysis. Data are presented as means  $\pm$  standard deviation (SD). Descriptive statistics were calculated and used to describe the aerobic and anaerobic fitness characteristics of the players. Spearman's Rank Correlation Coefficient was used on each dependent variable (movement time, penalties and total performance in LSPT) to examine the effect of aerobic and anaerobic fatigue on LSPT performance. Correlations were determined between pre- and post-test scores. The strength of the correlation was categorised as follows:  $\leq 0.01$  (trivial),  $< 0.3$  (small),  $< 0.5$  (moderate),  $< 0.7$  (large),  $< 0.9$  (very large) and  $\geq 1$  (perfect) (Hopkins, 2010). Differences in skill-related technical scores measured during the pre- and post-tests (speed, precision, success) were determined using a paired samples T-test, and the Cohen effect size (ES) was used to compare changes in performance between the pre- and post-test. Magnitudes of standardised effects were assessed as 0–0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large, and  $> 2.0$  very large (Batterham & Hopkins, 2006). The level of statistical significance was set at  $p \leq 0.05$ .

## **Results**

### **Physiological measurements**

Descriptive statistics for the Yo-Yo IR1 and RSA tests are presented in Table 1. Peak HR was slightly higher following the Yo-Yo IR1 than after the RSA test. Blood lactate measured after the RSA test was higher than blood lactate measured after the Yo-Yo IR1. The RPE (7.1) following the Yo-Yo IR1 and the RSA test was similar.

**Table 1: Descriptive statistics (mean ± SD) for the Yo-Yo IR1 and RSA tests**

	Yo-Yo IR1 (n=43)	RSA (n=48)
Total distance (m)	560.9 ± 212.8	614.3 ± 41.9
Peak HR (bpm)	190.1 ± 8.0	186.2 ± 8.9
Peak blood lactate (mmol/L)	11.2 ± 3.2	16.4 ± 4.3
RPE	7.1 ± 1.9	7.1 ± 2.2
$\dot{V}O_{2max}$ (mL/kg/min)	41.1 ± 1.8	
Yo-Yo IR1 level	14.1 ± 0.9	

Note: SD: Standard deviation; RSA: Repeated-sprint ability; Yo-Yo IR1: Yo-Yo Intermittent Recover level 1

### Passing accuracy

The LSPT performance scores are presented in Table 2. The performance in the LSPT decreased during the post-tests following the fatiguing exercises generally with a small effect. The LSPT passing time increased following both the Yo-Yo IR1 and RSA tests. In particular, penalty time increased following the Yo-Yo IR1 ( $p < 0.001$ ; 32.6%) with a moderate effect. Penalty time increased with a small effect following the RSA test ( $p = 0.01$ ; 20.4%). This is evident in the decrease in precision of passes that ultimately resulted in deterioration in the total performance time following both tests. There were large correlations ( $r = 0.7-0.8$ ) between pre- and post-test trials for all variables following the Yo-Yo IR1. Moderate correlations ( $r = 0.6$ ) were also found between trials following the RSA test.

**Table 2: Results of the LSPT preceding (pre-test) and following (post-test) the Yo-Yo IR1 (n=43) and RSA test (n=48) (mean ± SD)**

	Pre-test (s)	Post-test (s)	Percentage change between trials (%)	Cohen d (ES)	<i>t</i>	df	<i>r</i>
<b>Yo-Yo IR1</b>							
Passing time	49.9 ± 6.7	50.6 ± 7.0	1.4	0.1	-1.157	42	0.8
Penalty time	18.7 ± 10.8	24.8 ± 11.3	32.6*	0.6	-4.978	42	0.7
Total time	68.5 ± 16.2	75.4 ± 17.2	10.1*	0.4	-4.369	42	0.8
<b>RSA</b>							
Passing time	51.7 ± 6.8	53.6 ± 8.8	3.7	0.2	-1.812	47	0.6
Penalty time	22.1 ± 12.5	26.6 ± 13.5	20.4**	0.3	-2.638	47	0.6
Total time	73.8 ± 18.4	80.1 ± 21.1	8.5**	0.3	-2.548	47	0.6

Note: SD: Standard deviation; RSA: Repeated-sprint ability; Yo-Yo IR1: Yo-Yo Intermittent Recover level; ES: Effect size

\*  $p < 0.01$ : significant difference between pre-test and post-test; \*\*  $p < 0.05$ : significant difference between pre-test and post-test

## Discussion

Since many sports skills are executed in a fatigued state, a need exists to assess skill execution and performance in this condition (Lyons *et al.*, 2006). Limited studies have examined the effect of fatigue on LSPT performance (Lyons *et al.*, 2006; Rampinini *et al.*, 2008). To the researchers' knowledge, this is the first study to examine this effect using similar testing protocols. The main finding of this study was that both aerobic and anaerobic fatigue induced a decline in short-passing ability, consequently affecting technical performance negatively. The deterioration in short-passing skills may, therefore, be related to the accumulation of fatigue.

Research using an indirect measurement of  $\dot{V}O_{2max}$  on sub-elite female soccer players showed a mean value of 48.7 mL/kg/min (Vescovi *et al.*, 2006). Although data on sub-elite female players is limited, the present results were lower (41.1 mL/kg/min) than those previously reported, indicating a lower level of aerobic fitness. It is however important to note that even though a correlation exists between the Yo-Yo IR1 and  $\dot{V}O_{2max}$ , the range of the Yo-Yo IR1 test performance measured in distance can vary considerably (Bangsbo *et al.*, 2008). Although, this indirect measurement of  $\dot{V}O_{2max}$  is more time efficient and less expensive (Bangsbo *et al.*, 2008). The distance covered in the Yo-Yo IR1 was considerably lower than the distance indicated in a previous report (889.5 m) for sub-elite players (Hasegawa & Kuzuhara, 2015). These previously reported results were 25% lower than those of national team players, confirming the correlation between the Yo-Yo IR1 performance and competitive level (Hasegawa & Kuzuhara, 2015). Elite players were able to achieve distances of 1 232–1 379 m (Krustrup *et al.*, 2005; Bendiksen *et al.*, 2013). Hence, players of the current study should improve their aerobic fitness level as a higher level of aerobic fitness (48.7–56.8 ml/kg/min) is required for players competing at a higher standard (Krustrup *et al.*, 2010; Dillern *et al.*, 2012; Haugen *et al.*, 2014).

Furthermore, players need to perform a number of short sprints, interspersed with periods of low to moderate activity or passive rest (Bishop & Edge, 2006; Mujika *et al.*, 2009). While a wide range of testing protocols exists for determining RSA (Gabbett, 2010; Krustrup *et al.*, 2010; Shalfawi *et al.*, 2014), comparisons between studies are difficult due to variations in protocols in terms of mode of exercise, duration of sprints, number of sprint repetitions, recovery type and training status of the players (Spencer *et al.*, 2005). In the current study, the players ran an average of 614 m during the RSA test. A study using a similar testing protocol on players of the same competitive level could not be found. Previous research on female soccer players makes reference to RSA tests of 7 x 30 m sprints (30 s active recovery) (Shalfawi *et al.*, 2014) and

6 x 20 m sprints (15 s active recovery) (Gabbett, 2010). Further research should be performed using a comparable testing protocol on sub-elite female players for future comparisons.

Added penalty time makes up most of the difference between the Yo-Yo IR1 and the RSA test, suggesting that aerobic fatigue hinders performance more than anaerobic fatigue. The reason for this could be twofold. Firstly, players experience temporary fatigue following phases of high-intensity exercise and undergo progressive fatigue throughout a match (Mohr *et al.*, 2005). A recent study found that an increased recovery duration resulted in an increased number of total passes and a higher percentage of successful passes in small-sided games (Köklü *et al.*, 2015). By increasing recovery duration during repeated bouts of high-intensity exercise, an increase in physiological recovery occurs that may assist in maintaining physical performance (Balsom *et al.*, 1992; McLean *et al.*, 2016). Hence, in contrast to the progressive fatigue built up during the Yo-Yo IR1 as a result of the longer time duration involved in completing the test and less recovery time (10 s) between running, sufficient recovery was promoted during the shorter RSA test with longer recovery time (35 s) between each bout. The longer recovery period during the RSA test could increase the physiological recovery of the body, leading to better technical performance.

Secondly, testing was conducted during the competition season, that is, before and following a major soccer tournament. During the competitive season, coaches and trainers often place more emphasis on anaerobic conditioning through technical-skill training and short, repeated sprints, neglecting the aerobic conditioning that receives more attention during the pre-season. It is possible that due to specific preparations for the major competition structured in this particular format, more emphasis was placed on anaerobic conditioning, clarifying why anaerobic fatigue did not influence technical-skill performance to the extent that aerobic fatigue did. Small-sided games are a popular method used to develop technical skills and physical capabilities such as aerobic endurance (Köklü *et al.*, 2015) and can be used as a tool for enhancing physiological and technical performance.

The decreased performance indicated in the LSPT is evidenced by the increase in passing time, penalty time and total time after both fatiguing exercises. It appears that players sacrificed accuracy of passes to maintain the speed to complete the LSPT. This phenomenon in which players modify speed and/or precision in an attempt to maintain performance has been previously demonstrated and is known as the speed-accuracy trade-off (Russell *et al.*, 2011). During the LSPT, the players were unable to sacrifice speed due to the time limit imposed and as a consequence, accuracy decreased. From the observations, it was evident that the performance decrement in motor control during the post-tests was due to the aerobic and/or anaerobic fatigue

experienced, which manifested itself through inaccurate passes. The players attained less perfect scores through not hitting the black strip in the middle of the bench and missing the target area or bench completely, which would have obvious consequences during a match. Furthermore, the fatigue led to players losing control of the ball.

From the observations, it can be posed that the performance detriment was, in part, due to the discomfort experienced by the players following the high-intensity fatiguing exercises, as is evidenced by the high blood lactate concentration levels measured following the Yo-Yo IR1 (11.2 mmol/L) and RSA (16.4 mmol/L) tests. The high blood lactate concentrations observed in soccer may be a reflection of an accumulated or balanced response to the numerous high-intensity activities performed (Bangsbo *et al.*, 2006:667). The rate of lactate removal depends on factors such as lactate concentration, activity during the recovery period and the aerobic capacity of players (Stølen *et al.*, 2005:509). Lactate responses in this study were higher following the anaerobic exercise, although aerobic fatigue had a higher negative effect on technical performance. In a study investigating small-sided games, regimes involving passive rest resulted in higher lactate responses in comparison to active rest (Arslan *et al.*, 2017). The active-resting regime used in the Yo-Yo IR1 may, therefore, enhance blood lactate removal in comparison to the passive-resting regime of the RSA test, which may explain the higher blood lactate concentration measured following the RSA test. Also, players with a higher  $\dot{V}O_{2max}$  may have lower blood lactate concentrations due to an enhanced recovery from high-intensity intermittent activity (Tomlin & Wenger, 2001:9).

Lactate formation is dependent on several factors, one of which is oxygen availability (Myers & Ashley, 1997). An increase in aerobic fitness could enhance recovery from anaerobic performance by supplementing anaerobic energy during exercise and providing aerobically derived energy at a faster rate during the recovery period (Tomlin & Wenger, 2001). Furthermore, improvements that aid the transport networks to and from the muscle such as increased blood flow could enhance the removal of lactate (Tomlin & Wenger, 2001). A decrease in oxygen availability (during the RSA test) results in decreased aerobic and increased anaerobic contribution to sprinting (Tomlin & Wenger, 2001), leading to higher blood lactate concentrations. However, the high blood lactate concentration level following the aerobic test together with the poor Yo-Yo IR1 performance indicates that the players' aerobic fitness is insufficient, thus resulting in a slower rate of lactate removal.

The RPE is also described as a valid marker of global exercise intensity (Hill-Haas *et al.*, 2011) that represents the athlete's own perception of training stress (physical and psychological stress)

and could thus be a valuable measure of internal training load (Impellizzeri *et al.*, 2004). Based on the interpretation of the RPE scale used, players experienced the fatiguing exercises as very difficult, and together with the high blood lactate levels, the aerobic and anaerobic tests were of sufficient intensity to exhaust the players before the LSPT.

Technical-skill performance may in addition be influenced by cognitive functions and concentration (Rampinini *et al.*, 2008; Russell *et al.*, 2011; Nédélec *et al.*, 2012). Perceptual abilities (reaction time, decision-making and anticipation) are important during competitive play and for the successful execution of soccer skills (Stone & Oliver, 2009; Nédélec *et al.*, 2012). When players are mentally fatigued, their ability to identify errors and subsequently to adjust performance is diminished (Smith *et al.*, 2016). Immediately following the fatiguing exercises, many players seemed unsteady. It appeared that some players focused more on the fatigue experienced than passing accurately and controlling the ball, resulting in more errors. Recently, LSPT penalty time proved to be higher in a mental fatigue condition, resulting in more passing and ball control errors (Smith *et al.*, 2016), which could explain the same tendency observed among the players in this study.

Although the researchers of this study were unable to determine the direct involvement of these cognitive aspects of performance on the decrement in technique execution, the development of a sensitive measure of soccer skill performance that incorporates perceptual skills and reflects the demands of competition could increase the ecological validity of these findings (Russell *et al.*, 2011). Furthermore, exercise has been identified as synonymous with arousal (Lyons *et al.*, 2006). A review reported five studies that found players' speed of responding and decision-making as demands increased were facilitated by exercise up to a point and thereafter, exercise resulted in a decline in performance (Tomprowski, 2003). The RSA test could have been sufficient to exhaust the players in a shorter time than the Yo-Yo IR1. However, the longer duration of the aerobic test, along with shorter recovery time during the Yo-Yo IR1 test (10 s) as opposed to recovery time during the RSA test (35 s), could have had a higher negative impact on concentration ability, leading to the larger decline in technique performance. Aerobic metabolism is the most important energy source for soccer players (Shalfawi *et al.*, 2014), and lapses in concentration and mental fatigue are considered factors contributing to more goals being scored towards the end of a match (Reilly, 1997). This ultimately leads to the conclusion that for the participants of this study, it is possible that aerobic fatigue affected technical-skill proficiency more than anaerobic fatigue due to mental fatigue and higher loss of concentration, which can be investigated in future studies.

## **Conclusion**

The findings of this study indicate that the decreased performance in the LSPT is related to the physical fatigue because of the fatiguing exercises, more significantly in regard to aerobic fatigue. Based on the researchers' interpretation of the percentage decreases in the LSPT variables measured, it seems that aerobic fatigue influenced technical performance more than anaerobic fatigue, which can be justified by the low aerobic fitness levels of the players. Future research should include direct analysis between performance results following the aerobic and anaerobic fatiguing tests to confirm this observation. Aerobic training receives more attention during the pre-season conditioning, while small-sided games and technical-skill training (short anaerobic bursts) are the main focus during the competition season. Recovery from high-intensity intermittent exercise can be enhanced through increased aerobic fitness; enhancing aerobic contribution consequently increases lactate removal. Although beyond the scope of this study, higher mental fatigue leading to lower levels of concentration following the more taxing aerobic fatiguing exercise could further explain this occurrence and should be considered in future studies. Regardless of the physical fitness level of the players, pacing strategies utilized throughout a match or execution of an assessment remains a contextual factor to consider in soccer. The practical importance of the present study is to include aerobic conditioning in the annual training cycle to increase resistance to fatigue during repeated sprint exercise, and this may benefit players by reducing the decline in short-passing ability. The inclusion of both aerobic and anaerobic fatiguing exercises into technical-skills training may help players to cope better with the demands of the game without compromising their ability to make accurate passes.

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**Key points:**

- The deterioration in short-passing ability may be related to fatigue.
- Aerobic fatigue has a higher negative impact on technical skill performance than anaerobic fatigue.
- Aerobic conditioning should be emphasised in the annual training cycle to increase resistance to fatigue during repeated-sprint exercise, which may benefit players by reducing the decline in short-passing ability.

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## **CHAPTER 5**

# **THE USE OF GPS ANALYSIS TO QUANTIFY THE INTERNAL AND EXTERNAL MATCH DEMANDS OF SUB- ELITE FEMALE SOCCER PLAYERS DURING A TOURNAMENT**

This article will be submitted for publication in the Journal of Strength and Conditioning Research. The article is included herewith in accordance with the guidelines for authors of this esteemed journal (included as Appendix E). However, to provide a neat and well-rounded final product for this thesis, the article has been edited to represent an actual published article as it would appear in this particular journal. This does not imply that the article has been accepted or will be accepted for publication. Consequently, the referencing style used in this chapter may differ from that used in the other chapters of this thesis.

**Title:** The use of GPS analysis to quantify the internal and external match demands of sub-elite female soccer players during a tournament

**Running head:** Quantifying match demands of female soccer players

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## **ABSTRACT**

The aim of this study was to assess the internal and external match demands of sub-elite female soccer players during a tournament. The secondary aim was to describe the magnitude of change of these variables within and between matches over the course of a tournament to determine the effect of player fatigue. Thirty sub-elite female soccer players were assessed throughout a local tournament. Differences in match demands within and between matches were assessed using percent difference, effect size and 90% confidence intervals. The participants covered an average distance of 5917 m during the matches. Midfielders covered the greatest absolute and relative total distances, and achieved the highest low-intensity activity and player load per minute of play. Defenders covered less ( $p \leq 0.05$ ) relative distance and low-intensity activity per minute of play compared to midfielders. Forwards covered the greatest distance at high-intensity, while the greatest percentage of time at high-intensity heart rate was measured among the defenders. Within match comparisons revealed that player load decreased significantly ( $p \leq 0.05$ ) in the second half (ES: 0.4). Relative distance, low-intensity activity and high-intensity activity also decreased in the second half with possibly trivial to likely small changes. Small to large differences in variables were observed throughout the tournament. The biggest magnitude of change was seen with a large decrease (ES: -1.2) in relative distance covered between match 2 and 5. Despite generally small reductions in performance measures, there is evidence that accumulated fatigue throughout a multi-day tournament would affect performance negatively.

**KEY WORDS:** GPS, heart rate, HIA, match analysis, player load

## **INTRODUCTION**

The soccer milieu has seen a considerable increase in female soccer players participating in international competitions, professional and recreational leagues (31). Female players now have the opportunity to train and compete in professional settings, which gave rise to an increase in the performance expectations placed upon players, and subsequently a need for specific scientific research that could assist to enhance performance (31). The successful evaluation of the physical demands placed upon soccer players requires accurate assessment of both internal and external match demands (21). Wearable technology such as global positioning system (GPS) devices simultaneously used with heart rate (HR) monitoring, are commonly used in elite sport to monitor the internal and external loads of athletes in order to assess physiological and movement demands (4, 6, 14). The use of GPS technology further allows for direct measurement of a player's movement during a match as opposed to the subjective determination of movement by an observer as required with video analysis (39).

Movement activities in soccer are generally classified according to intensity, determined by the speed of the action (12). Match analysis of locomotor activities performed over different velocity zones (especially at high-intensity) attracts more attention in literature, since it reflects the physical demands of competition (34). Although a large part of a match consists of walking or jogging, it is important to determine the pattern of high-intensity work performed (22), as high-intensity movements have been shown to vary between different levels of participation (22, 29, 34). Studies using GPS found that elite and sub-elite female soccer players cover a total distance of around 8–11 km during a match, ranging between 108–119 and 96–107 metres per minute of play (m/min) for elite and sub-elite players respectively (1, 9, 22, 32, 34, 37, 41), while sprinting and HIR constitutes 8–12% of the total distance covered (1, 10, 20, 27, 32). Midfielders tend to cover the greatest total distance during a match and cover more distance at HIR and sprinting, while defenders cover the shortest total distance as well as distances at HIR and sprinting (1, 22). However, the distance covered at different running speeds should not be the only consideration when evaluating a player's total work load (15). Player load is a representation of total body load expressed in arbitrary units and involves the measurement of three dimensional body movements with triaxial accelerometers (5, 15). Certain high-intensity soccer-specific movements classified as low-speed movements such as jumping, tackling, collisions, accelerations, decelerations, passing, shooting, sideways and backward running, have been neglected, leading to an underestimation of physical stress, even though it can place high physical strain on players (15). Player load is also found to differ between playing positions in male soccer, with midfielders achieving a higher player load compared to forwards and defenders (5, 15). To the author's

knowledge no data is available on female soccer examining player load according to playing positions.

Internal load is perceived as a player's response to an external physical stimulus (36). Heart rate measurement is often used as an indirect measure of exercise intensity and used to examine the internal load of players during training or competition (16, 33). A method commonly used to quantify internal match load is to describe the amount of time spent in different intensity zones based on the percentage of maximum HR ( $HR_{max}$ ) (8, 33). Average HR and peak HR values of 84–89% and 98–100% of  $HR_{max}$  respectively have been reported for female soccer players during matches (1, 28, 33). This is an indication that female players experience a high aerobic load throughout a match with periods of near-maximal values (27). Significant differences in HR recordings between the first and second half are also evident (33). Peak and mean HR recorded during the first half were higher than the second half (33, 35). Further analysis showed that a reduction occurred in the time spent in the intensity zone above 95% (33).

Apart from performance assessment during individual matches, the ability of female soccer players to repeat high-intensity efforts on numerous occasions over several days along with the changes in movement patterns over the course of a tournament, have not been examined previously. It is believed that the physiological stress experienced by players result in fatigue that leads to a decrease in performance (30). In order to perform optimally, appropriate recovery interventions in competitive tournaments and between matches are important (2). It is also claimed that players regulate exercise intensity throughout matches to ensure sufficient physiological reserves to complete that match (18). Pacing strategies utilised throughout a match therefore remains a contextual factor to consider in soccer.

To date, limited literature exists on the position-specific match-related locomotor categories, player load profiles and internal match demands of female soccer players. Also, it has yet to be clarified what affect a week-long tournament has on running intensities and movement patterns. A detailed analysis of the internal and external load within a match and throughout a tournament gives a greater insight into the physical demands of female soccer and the requirements over the duration of such a tournament. Highlighting meaningful performance characteristics associated with the demands of female soccer through match analysis is essential to provide information to coaches and conditioning specialists towards prescribing and implementing sport-specific conditioning programmes that replicate the physical demands of competition and adjusting physical preparation to the precise requirements of each position. The primary aim of this study was to assess the internal and external match demands of sub-elite female soccer players during

a tournament. The secondary aim was to describe the magnitude of change of these variables within and between matches over the course of a tournament to determine the effect of player fatigue. The hypothesis of the study is that the internal and external match demands of sub-elite female soccer players will differ within and between matches in a tournament.

## **METHODS**

### **Experimental approach to the problem**

An observational study was conducted to compare the internal and external match demands of sub-elite female soccer players according to playing positions and the role of fatigue during ten official matches of a club championship. Each team was monitored for five matches during the course of a week-long tournament. The matches were played on a standardised soccer field and consisted of two 35 minute halves. Comparisons were made based on different GPS-derived variables, including total distance, distances covered in different velocity zones, high-intensity activities and corresponding heart rates, work rate and player load.

### **Subjects**

Thirty sub-elite female soccer players (age:  $22.8 \pm 2.4$  years; height:  $158.6 \pm 4.5$  cm; body mass:  $54.1 \pm 6.1$  kg) representing two university teams participated in the study. The teams were purposefully selected and representative of sub-elite level players during a university tournament. Data of players who completed full matches were retained for analysis. Players were categorised according to playing position, namely forwards (FW), midfielders (MF) and defenders (DF). Prior to data collection, ethical approval was obtained from the university's Health Research Ethics Committee (NWU-00055-15-A1). Research was conducted according to the declaration of Helsinki. Anonymity was ensured through assigning participant numbers. Written informed consent was obtained from all the players before commencement of the assessment procedures.

### **Procedures**

#### ***Match analysis***

Only the activity profiles of the starting line-up were recorded during all matches, providing a total of 84 individual match files. Goalkeepers were excluded from the analysis. Matches were analysed with GPS units sampling at 10 Hz and equipped with 100 Hz accelerometer (MinimaxX S4 V4.0, Catapult Innovations, Victoria, Australia). GPS units were fitted to the upper back of each player using a harness. Units were turned on 10 minutes before each match during

the pre-match warm-up. For a movement to be recorded as an effort, players had to maintain that specific velocity for at least 0.5 sec. Locomotor activities were defined as previously reported for female soccer players (11, 40, 41): standing and walking (0.0–1.6 m/s), jogging (1.7–2.2 m/s), low-intensity running (2.3–3.3 m/s), moderate-intensity running (3.4–4.3 m/s), high-intensity running (4.4–5.6 m/s) and sprinting (>5.6 m/s). Data were normalised to distance per minute played (m/min) to account for differences in total playing time and in match stoppages. For statistical analysis, data were categorised into total distance (m), relative distance (m/min), low-intensity activity per minute (LIA/min) (consisting of standing/walking, jogging and low-intensity running), moderate-intensity running (MIR), high-intensity activity per minute (HIA/min) (consisting of high-intensity running and sprinting), player load per minute (PL/min) and high-intensity heart rate per minute (HIHR/min). Player load was determined by the software using the following formula:  $(a_{y1}-a_{y-1})^2 + (a_{x1}-a_{x-1})^2 + (a_{z1}-a_{z-1})^2$ , where  $a_y$ =anteroposterior acceleration,  $a_x$ =mediolateral acceleration, and  $a_z$ =vertical acceleration. Horizontal dilution of precision (HDOP) indicates accuracy of GPS in a horizontal plane and optimum satellite availability. During the tournament the average HDOP was 1.06. Data recorded on GPS units were downloaded onto a PC and analysed using the Logan Plus V4.7.1 software (Catapult Sports, Victoria, Australia). An intelligent motion filter was used to exclude non-game activity. The raw data were also further divided into first half and second half files. GPS Doppler data were used during analysis of the GPS-related variables. The validity and reliability of the GPS units have been reported previously (38).

### **Heart rate monitoring**

Heart rate (HR) was recorded individually through a Fix Polar Heart Rate Transmitter Belt (Polar Electro, Kempele, Finland) at five second intervals during the matches. The transmitter belts were fitted to each player before the match.  $HR_{peak}$  was defined as each individual's maximum HR collected during the matches, which were then used for match analysis. Heart rate values were divided into six intensity zones: <60%, 60–75%, 75–85%, 85–90%, 90–95%, and >95% (3). High-intensity exercise, described as HIHR in this study, was defined as exercise intensity with a HR above 90% of  $HR_{peak}$  (13). The percentage of time spent in HR zones was used for analysis. Before data analysis commenced, players were excluded if they had missing data.

### **Statistical analysis**

Variables were log transformed to reduce bias due to non-uniformity of error and analysed using the effect size (ES) statistics with 90% confidence intervals (CI) and percent difference to

determine the magnitude of effects using a custom spreadsheet (24). Magnitude-based inferences on differences within and between matches were made by standardising differences using the between-subject SD. Descriptive statistics are presented as mean  $\pm$  standard deviation and were used to characterise movement patterns. Data are expressed relative to game time played (per minute) to account for variations in playing time from match-to-match. Differences in the match demands and running intensities among playing positions were compared using one-way ANOVA. Where significant effects of position were observed, Bonferroni corrections were used to determine differences in positions. A paired sample t-test in conjunction with the Cohen effect size was used to compare changes in match performance between the first and second halves and between individual matches. Magnitudes of standardised effects were assessed as 0–0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large, and >2.0 very large (7). The effect was reported as unclear when the CI of the standardised difference crossed the threshold for both substantially positive (0.2) and negative (-0.2) values. The quantitative chances of finding differences were assessed qualitatively as follows: < 1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; > 99%, almost certain. The level of statistical significance was set at  $p \leq 0.05$ .

## RESULTS

Table 1 displays the match demands with relevance to playing positions. Midfielders covered the greatest total distance (6065 m), followed by forwards (5847 m). Defenders covered the least total distance (5567 m) throughout the matches. Midfielders covered greater ( $p \leq 0.05$ ) relative total distance (84.4 m/min) and LIA (72.2 m/min) per minute of play compared to defenders. Forwards performed more HIA (4.9 m/min) per minute of play compared to the other playing positions, although this difference was not significant. Midfielders achieved a higher player load (9.7 PL/min) compared to both forwards (8.3 PL/min) and defenders (8.6 PL/min). Furthermore, defenders spent the greatest amount of time (13.3%) in the HIHR zone, and forwards the least (9.7%).

**Table 1: Match demands according to positional groups. Data are displayed as mean  $\pm$  SD (and 90% CI).**

Variables	Forwards	Midfielders	Defenders
Total distance	5847 $\pm$ 739 (5510–6183)	6065 $\pm$ 880 (5764–6366)	5567 $\pm$ 818 (5333–5801)
PL/min	8.3 $\pm$ 0.9 (7.9–8.7)	9.7 $\pm$ 1.9 (9.0–10.3)	8.6 $\pm$ 1.6 (8.1–9.1)
m/min	80.4 $\pm$ 9.8 (75.9–84.9)	84.4 $\pm$ 12.5 (80.1–88.6)	76.9 $\pm$ 10.7 (73.8–79.9)*
LIA/min	68.9 $\pm$ 9.3 (64.6–73.1)	72.2 $\pm$ 10.0 (69.3–76.1)	66.7 $\pm$ 8.0 (64.4–69.0)*
HIA/min	4.9 $\pm$ 1.9 (4.0–5.7)	4.7 $\pm$ 3.1 (3.6–5.7)	4.7 $\pm$ 2.8 (3.9–5.4)
HIHR/min	9.7 $\pm$ 10.2 (5.1–14.4)	12.8 $\pm$ 17.1 (7.0–18.7)	13.3 $\pm$ 15.9 (8.8–17.8)

Note: CI: Confidence interval; SD: Standard deviation; HIA/min: high-intensity activity per minute; HIHR/min: high-intensity heart rate per minute; LIA/min: low-intensity activity per minute; m/min: meterage per minute; PL/min: player load per minute

\* Significantly different from Midfielders ( $p \leq 0.05$ )

Mean HR recorded during the matches was 159 beats per minute (bpm), which corresponded to 81% of  $HR_{peak}$  being 197 bpm. Mean HR was higher (ES: 0.3) during the first compared to the second half (162 vs 157 bpm), corresponding to 82% and 80% of  $HR_{peak}$  respectively. Players spent the greatest amount of time in the 75–85% of  $HR_{peak}$  zone (Figure 1), and spent a combined total of 13% of the total time in the HIHR zones of 90–100% of  $HR_{peak}$ .

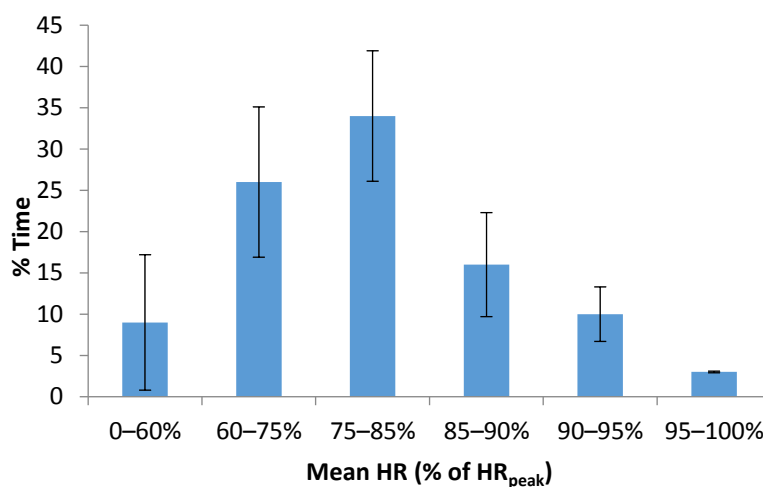


Figure 1: Percentage of time spent at the intensity zones of HR<sub>peak</sub> during match play

Differences in match demands between the first and second half are presented in Table 2. Although player load decreased ( $p \leq 0.05$ ) from the first to the second half, the effect was likely small. Similarly, all other match variables decreased during the second half and displayed possibly trivial to small effect sizes.

Table 3 indicates the magnitude of change between matches over the course of the tournament. When comparing Match 1 with Match 2, 3, and 4, likely small to moderate positive changes were observed for PL, relative distance and LIA, while a positive change (likely moderate) for HIA was only observed from Match 1 to Match 2. Furthermore, with the exception of the possible moderate positive change observed for PL between Match 3 and 4, all the other changes observed for the remaining match comparisons were negative, and mostly ranged between small and moderate, although a probable large negative change was identified between Match 2 and 5 in terms of relative distance covered. Unclear changes were noticed between Match 2 versus Match 3 and 4, and Match 3 versus Match 4 for LIA, and also between Match 1 versus Match 3 and 4, and between Match 3 versus Match 4 and 5 for HIA. In terms of internal demands assessed, changes in time spent at HIHR ranged between trivial and small, and did not seem to follow a specific trend for increases or decreases observed.

**Table 2: Difference in match demands between first and second half (mean  $\pm$  SD)**

Variables	First half	Second half	<i>p</i>	Cohen d $\pm$ 90% CI	Practical outcome
PL/min	9.1 $\pm$ 1.6	8.5 $\pm$ 2.1	0.02*	0.4 (0.1–0.6)	Likely small
m/min	82.8 $\pm$ 11.7	76.4 $\pm$ 15.6	0.07	0.3 (0.0–0.5)	Possibly small
LIA/min	71.4 $\pm$ 9.3	66.0 $\pm$ 12.9	0.07	0.3 (0.0–0.5)	Possibly small
HIA/min	4.9 $\pm$ 3.1	4.6 $\pm$ 2.6	0.95	0.1 (-0.2–0.3)	Possibly trivial
HIHR/min	14.6 $\pm$ 17.3	10.3 $\pm$ 2.3	0.57	0.1 (-0.2–0.4)	Possibly trivial

Note: CI: Confidence interval; SD: Standard deviation; HIA/min: high-intensity activity per minute; HIHR/min: high-intensity heart rate per minute; LIA/min: low-intensity activity per minute; m/min: meterage per minute; *p*: significance; PL/min: player load per minute

\* Significantly different from first half ( $p \leq 0.05$ ).

**Table 3: Magnitude of change (mean ± 90% CI) and effect sizes (90% CI) of match demands over the course of a soccer tournament. Chance that magnitude of change between two games is higher/no difference/lower (100/0/0).**

Variables		M1 v M2	M1 v M3	M1 v M4	M1 v M5	M2 v M3	M2 v M4	M2 v M5	M3 v M4	M3 v M5	M4 v M5
PL/min	% Diff	18.0±15.0	12.6±15.7	14.7±16.7	-7.1±33.7	-5.5±4.1	-2.7±5.3	-9.0±16.6	2.9±4.5	-5.5±16.1	-6.9±14.8
	ES and 90%CI	0.6 (0.1 –1.1)	0.4 (-0.1– 0.9)	0.5 (-0.1– 1)	0.3 (-1.3 – 0.7)	-0.3 (-0.6 – -0.1)	-0.2 (-0.5–0.1)	-0.5 (-1.4 –0.3)	0.2 (-0.1 –0.5)	-0.4 (-1.3 –0.6)	-0.4 (-1.3 –0.4)
	QO.	90/9/1	77/20/3	81/16/2	21/25/54	0/18/82	3/57/40	8/17/75	45/53/1	16/23/61	10/21/69
m/min	% Diff	16.2±14.6	12.8±16.6	13.2±17.0	-8.5±35.4	-3.1±2.5	-3.2±3.6	-12.6±16.0	-1.5±3.5	-10.5±14.2	-8.3±14.4
	ES and 90%CI	0.7 (0.1 –1.4)	0.6 (-0.2 –1.3)	0.6 (-0.2 –1.4)	-0.4 (-1.9 –1.0)	-0.3 (-0.5 –-0.1)	-0.3 (-0.6 –0.0)	-1.2 (-2.6–0.1)	-0.2 (-0.5 –0.2)	-1.1 (-2.4 –0.2)	-0.6 (-1.6 –0.4)
	QO.	91/7/2	82/14/4	82/14/4	22/16/61	0/25/75	1/29/70	4/6/90	4/56/39	5/7/88	8/15/78
LIA/min	% Diff	12.6±13.4	11.4±15.1	13.4±15.1	-6.4±32.9	-0.7±2.7	-0.3±3.0	-9.2±14.5	-0.9±3.1	-9.5±12.7	-7.6±13.7
	ES and 90%CI	0.6 (-0.0 –1.2)	0.5 (-0.2 –1.3)	0.6 (-0.1 –1.3)	-0.3 (-1.8 –1.1)	-0.1 (-0.3 –0.2)	-0.0 (-0.3 –0.3)	-1.0 (-2.3 –0.4)	-0.1 (-0.4 –0.2)	-1.0 (-2.2 –0.2)	-0.7 (-1.7 –0.4)
	QO.	86/11/2	80/15/4	85/12/3	25/18/57	4/77/19	10/75/16	7/9/83	5/67/27	5/8/87	9/14/77

Variables		M1 v M2	M1 v M3	M1 v M4	M1 v M5	M2 v M3	M2 v M4	M2 v M5	M3 v M4	M3 v M5	M4 v M5
HIA/min	% Diff	52.3±39.6	-3.8±39.4	-0.6±47.1	-32.1±91.1	-35.3±21.4	-32±15.7	-40.6±58.7	1.8±15.4	-7.9±58.2	-17.6±46.4
	ES and 90%CI	0.8 (0.2 –1.5)	-0.1 (-0.7 –0.6)	-0.0 (-0.8 –0.8)	-0.8 (-2.1 –0.5)	-0.7 (-1.0 –-0.4)	-0.6 (-0.9–-0.4)	-0.8 (-1.6 –-0.1)	0.0 (-0.2 –0.3)	-0.1 (-0.9 –0.6)	-0.4 (-1.2–0.4)
	QO.	94/5/1	23/40/37	31/35/33	10/12/78	0/1/99	0/0/100	1/6/92	11/83/6	22/33/44	10/22/67
HIHR/min	% Diff	-46.0±173.8	-22.8±312.9	-23.3±242.9	224.4±459.9	-36.6±51.9	0.4±82.8	-13.1±1544.4	27.9±93.8	178.0±356.8	75.6±164.3
	ES and 90% CI	-0.5 (-1.4 –0.3)	-0.2 (-1.4–1.0)	-0.2 (-1.3–0.8)	1.0 (-0.5–2.4)	-0.3 (-0.6–-0.0)	0.0 (-0.4–0.4)	-0.1 (-1.9–1.8)	0.2 (-0.4–0.8)	1.0 (-0.5–2.4)	0.5 (-0.3–1.3)
	QO.	7/17/76	26/24/51	22/27/52	84/8/8	1/24/75	19/63/18	37/18/45	54/36/11	85/7/8	74/18/8

Note: %Diff- percentage difference; CI: confidence interval; ES: effect size; HIA/min: high-intensity activity per minute; HIHR/min: high-intensity heart rate per minute; LIA/min: low-intensity activity per minute; m/min: meterage per minute; M1: match 1; M2: match 2; M3: match 3; M4: match 4; M5: match 5; PL/min: player load per minute; QO.: qualitative outcome

## **DISCUSSION**

This is the first study to describe the match demands and movement profile of South African sub-elite female soccer matches. Unique to this study was the use of velocity zones specific for female field sports in the categorisation of locomotor characteristics (41) and to determining the influential role of fatigue within and throughout a tournament. The study also distinctly compared between positional differences, adding to the limited studies conducted on sub-elite level, and broaden our knowledge on what is regarded as a gap in female soccer. The results of the study support the hypothesis that all the variables studied would show reductions during the course of a tournament over consecutive days. This was specifically apparent from the second to the last match of the tournament. Direct comparisons were limited due to shorter match periods used in the current study compared to other studies on female players. This was due to the design of the tournament during which data collection was conducted, whereby matches were played on consecutive days for a total of five days to determine the winner of the tournament. This structure is specifically used each year during this particular local soccer tournament on sub-elite level and is not typical of national or elite level tournaments. Studies reporting on the match-to-match comparisons throughout a female soccer tournament do also not exist. Though, similar trends for positional differences during a match were noted in comparison with other studies on female players.

The total absolute (5759 m) and relative (80 m/min) distances measured in the current study are lower than those reported for elite female players (1, 9, 32, 34, 40, 41). Currently, no methodological standardisation of velocity thresholds to accurately quantify locomotor activities during female soccer matches exists, limiting comparisons between studies to develop cohesive views concerning locomotor characteristics of female soccer (11). In line with previously described velocity zones used for female players (40, 41), the amount of distances covered by the players from the current study in each velocity zone differed, with players spending 42% standing/walking, 11% jogging, 23% LIR, 11% MIR, 5% HIR and 1% sprinting. Specifically in the HIR and sprinting zones, performance was lower than previous findings (7.5% HIR and 2.5% sprinting) for sub-elite players (41). These findings can be influenced by elements such as physical fitness of the players, game strategies of the players, opposition team standard and formations (22, 29, 30, 32).

Similar to previous studies using GPS or video analysis (32, 34, 40, 41), positional distinctions were evident, with midfielders recording the furthest absolute total distance. Consequently, midfielders achieved the highest relative total distance, which was significantly greater than the results noted for defenders, who, in agreement with a previous study (41), achieved the lowest relative total distance. The greater total distance by midfielders over forwards and defenders was

predominantly from more LIA per minute of play, which was also greater than the distance reported for defenders. This finding can be attributed to the positional demands of midfielders fulfilling a linking role between the front and back players, justifying the higher work rate (17). Results further concur with previous findings on sub-elite female players whereby forwards covered the greatest distance at HIA (consisting of HIR and sprinting) (41). However, studies on elite female players reported more ( $p \leq 0.05$ ) HIR distance for midfielders compared to defenders, while forwards covered more distance at HIR and sprinting compared to defenders (22, 32). Greater sprint distances during a match may be a result of performing more sprints rather than longer sprints (40), possibly explaining the transition from sub-elite to elite level performance whereby midfielders perform more HIA than the other playing positions. This finding could be of importance to coaches and conditioning specialists in planning training programmes to enhance position-specific performance to compete on a higher standard.

The use of player load in addition to GPS-based speed data may provide a more accurate indication of the demands imposed by soccer-specific non-running activities (36). Player load is found to differ between playing positions in youth male soccer players (5). A study on female soccer players examining player load using a similar method could not be found, and therefore comparisons are limited and results of the current study are discussed in line with tendencies found among male soccer players concerning playing position. A difference ( $p \leq 0.05$ ) was found between the player load of midfielders compared to forwards and defenders, while forwards and defenders had comparable values. Due to correlations found previously between player load and methods used to assess internal training load and session-RPE, it was suggested that player load is an acceptable measure of external training load and is mainly related to a player's physiological and perceptual responses to a training stimulus (36). Once again the higher player load recorded for the midfielders can be justified by the linking role these players fulfil during a match (17). It can in addition be posed that the higher level of manoeuvrability required by midfielders to perform their positional tasks could have a higher player load as a result due to performing more movement activities at both low- and high intensity. With the purpose of designing training programmes specific to the different playing positions, an understanding of the different ways in which players from these different positions achieve load is necessary (15). Since player load is achieved by players from different positions in a variety of ways, specificity should be applied when compiling training programmes with distinct emphasis on the physical components required to achieve a stimulating load in relation to each position's requirements (15). Differences in playing formations, playing standards, effective playing time and score line are all factors that would affect positional activity profiles and should be considered when making comparisons (5).

It is believed that, in team-sport match analysis, the players' inability to maintain the running performance within the first half of a match to the second half suggests player fatigue (19). Total distance within matches decreased ( $p \leq 0.05$ ) with 11% from the first to the second half. Studies on elite level female players also noted differences (4%;  $p \leq 0.05$ ) between the first and second half (1, 32). Although not significant, relative total distance decreased with a possible small effect (8%) from the first to the second half. This change was attributable to a 7% (ES: likely small) decrease in LIA and a 6% (ES: possibly trivial) decrease in HIA across halves. Player load decreased ( $p = 0.02$ ; ES: likely small) across match halves, suggesting more movement activities performed during the first half. These results suggest that the players either exert more efforts/intense movements during the first half, which can be explained by a particular strategy used by the players in order to physically challenge and exhaust the opposing team more during the first half in an attempt to gain a competitive advantage in the second half. Alternatively, these results could be evidence of fatigue experienced in the first half leading to lower performance in the second half. The reduction of HIR towards the end of a match could be a result of fatigue, but can also be influenced by other factors such as game tactics (1, 32). Improving female players' ability to perform HIA towards the end of a match (through high-intensity aerobic and speed-endurance training) should be emphasised in training programmes, consequently equipping players with the possibility of out-playing the opponent and creating more scoring opportunities.

The findings of the current study suggest that the players need to improve their physical condition, specifically to perform more and longer HIA, which may be a contributing factor towards progressing towards competing at a higher standard. The tournament structure and number of matches played within the week should, however, also be considered when interpreting these results. The influence of multiple matches on exercise intensity and the effect of fatigue during a tournament has been investigated in other field team sports (25, 26). Increased match intensity and frequency highlight the importance of proper recovery interventions between matches in order to continually perform at an optimal level (2). Since players have limited time to recover before the next match, the ability to maintain exercise intensity throughout a tournament could be of importance, considering the possibility that players may experience accumulated fatigue (26). It appears that when Match 1 was compared to Match 2, 3 and 4, the positive changes observed in relative distance, LIA and PL are an indication of likely small to moderate higher performance, with the lowest performance produced in Match 1. The lower performance produced in Match 1 can possibly be attributed to a pacing strategy employed in an attempt to conserve energy for the coming matches (23). It is also reasonable to expect that during the first match the players experienced a higher level of anxiety as it is the start of a tournament, which could have resulted

in players not performing to the best of their abilities. These factors are worth considering in future studies to contribute to studies of this nature. The match-to-match comparisons of HIA performed resulted in a different outcome. A likely moderate increase in HIA was evident from Match 1 to Match 2, while the decreases observed from Match 1 to Matches 3 and 4 were trivial and unclear. Although comparisons between Match 1 and 5 in terms of relative distance, LIA and PL indicate small changes, these results are unclear due to the magnitude of difference, and it would therefore not be accurate to draw a conclusion on the role of fatigue based on this comparison alone. The biggest decrease was observed in the HIA movements with moderate effect in comparing Match 1 with Match 5, even though unclear, these results still suggests a decrease in HIA from the first to the final match. This could be an indication of the effect of accumulated fatigue on HIA movements during and at the final stages of a tournament and should be considered in future studies on players competing in a similar tournament structure.

Furthermore, between match analyses from the second to the final matches generally showed gradual but small to moderate reductions in variables measured. These results are in accordance with differences observed in running intensities performed at low and high velocity zones throughout field hockey and rugby tournaments (23, 25, 26). It is in addition possible that differences in PL may not be an indication of fatigue, which can probably be attributed to the fact that PL is determined by a variety of movements commonly classified as low-activity movements but which could still contribute highly to the fatigue of a player. The preservation of performance between Matches 2, 3 and 4 suggests that transient fatigue is accumulated during a match and that accumulated fatigue has a minimal effect on performance during Match 3 and 4. It is also possible that a specific pacing strategy was used or sufficient recovery methods employed to minimise fatigue build-up in a tournament of this particular structure, or that a combination of these tactics assisted in relative maintenance of performance (23). The importance of Match 4, which in this tournament was the semi-finals, could also have played a role in the relative maintenance of performance in this match. Since Match 4 was a qualifier to progress to the finals, it is typical to expect that players would maximise their efforts in a last attempt to progress to the final match of the tournament. Although, the reduced performance measured across all variable in the final match should provide sufficient evidence of the effect of residual fatigue from the previous match and accumulated fatigue throughout the tournament, resulting in decreased intensities at the end of a tournament. A study on female soccer players found that all neuromuscular parameters, including sprint performance, were considerably altered after a match, and muscle damage indicators (creatinase kinase and muscle soreness) were elevated for numerous days (2). The study further explained that mean HR value and HIR performance were

not impaired where two matches were interspersed by two days. In the current study, the load of the competition may have impaired the players' performance due to insufficient recovery between matches, consequently leading to shorter distances covered in total and within each velocity zone, specifically at HIA. Another notion to consider is the role of opposition team standard. Player density and space available for running may be reduced in matches against higher- or lower ranked teams (22). A team dominating ball possession can lead to a greater number of players in one half of the field, thereby decreasing running space, while playing against opposition of relatively similar strength increases opportunities to move from the defensive to the offensive half (22). During the tournament, the players played against teams of different strengths and rankings, which could have influenced distances covered and HIA. Match analysis of all teams within such a tournament are recommended for future analyses in order to compare teams of different ranking and make conclusive recommendations. These, along with the recovery period are important aspects for consideration by coaches, conditioning specialists and tournament organisers in planning to improve the conditioning status of the players, consequently enhancing performance and allowing for optimal performance during matches.

The clarification of internal match demands in addition to external demands could provide a more detailed description of the physical demands placed on soccer players. An advantage of HR monitoring during a match is the possibility of recording the response of several players taking part in the same specific playing situation, making it a helpful tool coaches can use to control the aim of training and preparing players for matches (33). Vital information provided by HR monitoring can assist to prevent overtraining or understimulation of the cardiovascular system (33). The average HR reported in the current study was lower than previous reported values for competitive matches of elite female players (1, 28, 33). When expressed according to the percentage of time spent in different HR zones based on  $HR_{peak}$ , the results of the players in the current study differed from a previous report on elite female players (33). The players in the current study spent most of the time in zones 60–75 and 75–85% of  $HR_{peak}$ , whereas elite players spent the least amount of time in these two zones (5 and 18%, respectively) (33). Elite players also spent the highest amount of time (32%) in the 90–95% of  $HR_{peak}$  zone in contrast to the 10% achieved by the players of the current study, and spent a combined total time of 55% at HIHR (>90% of  $HR_{peak}$ ) (33). It is evident that performance at HIHR may be a factor distinguishing female players of different standards. Furthermore, defenders and midfielders spent more time than forwards in the HIHR zones, possibly indicating a higher physical load on these players due to positional responsibilities. The reduced time spent in the HIHR zones in the second half suggests a decrease in the physical work performed and the occurrence of physical fatigue (35). A

possibility exists that the magnitude of change observed in HIR/min is related to the results noted for HIHR/min and recommends further research, as both these measures produced only possible trivial reductions. Unlike with the external match demand variables discussed, no specific tendency for between match comparisons throughout the tournament could be noted for time spent at HIHR. Changes ranged between trivial and small, but did not follow a specific trend regarding increases or decreases observed. Even though it appears in this study that HIHR may not be a factor to consider in isolation when discussing match demands throughout a tournament, more research is required to justify the current findings.

In conclusion, although playing time was shorter, the players in the current study achieved lower distances at HIA in comparison to players of similar and higher standard, and also lower absolute and relative total distances. The amount of HIA is lowered towards the second half of a match, suggesting the possibility of fatigue influencing HIA movements. Altogether, these findings indicate that sub-elite female players experience fatigue during a match and throughout a tournament consisting of matches played on consecutive days. Positional specificity is also apparent. Sport scientists and researchers are encouraged to use specific velocity zones associated with female players and to consider the variables identified, in order to create consistency and elaborate on the limited data available, thereby expanding the possibility for comparing and justifying results and compiling position-specific training programmes. The tactical use of player substitutions by coaches in the latter periods of a match could be a strategy in an attempt to lessen the effect of fatigue on the players' and teams' performance. Although the movement profile of substitute players was beyond the scope of this paper and warrants future studies. The present findings give a unique description of the match demands of sub-elite female soccer players within the specific context of playing 5 matches on consecutive days. It identifies specific changes in match variables throughout a tournament, which can be attributed to accumulated fatigue, filling a critical knowledge gap in South Africa and adding to what is currently known about players on sub-elite level worldwide.

## **PRACTICAL APPLICATIONS**

Players in the current study covered a much lower distance at HIA in comparison to previous studies. Soccer conditioning specialist and coaches should identify the reason for this finding and improve the players' physical conditioning should fitness be the cause of lower performance. Running requirements may also be influenced by technical and tactical abilities. An important factor to consider is the structure of the tournament during which data collection occurred. It is possible, due to consecutive matches being played, that the physical attributes of the players

were compromised by factors such as insufficient recovery periods between matches, leading to fatigue and possibly injuries. This could have affected their performance towards the end of the tournament, resulting in lower distances recorded and decreased performance. This is the first study to profile the positional player load during competitive sub-elite female soccer matches. The current study identified positional differences and provides greater insight into the internal and external match demands of female soccer. In summary, this research elaborates on the limited literature on the match demands of sub-elite female soccer players and can assist coaches and strength and conditioning specialists to compile training programmes to appropriately develop female soccer players on sub-elite level and improve performance on the field. Small reductions in the work rate of players can be expected between the first and second half of a soccer match and the use of tactical player substitutions can assist to maintain the work rate of the team. Reports analysing movement patterns per minute of play is necessary to account for these differences in match time variability.

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## **CHAPTER 6**

# **SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS**

## 6.1 Summary

Women's soccer is regarded as one of the most popular female sports worldwide. The opportunities for female players to compete on higher levels have seen a considerable increase, allowing players to compete on national and professional level. Apart from specific positional requirements, players need to perform a variety of actions when competing, making it crucial for players to adapt to the multi-factorial demands of a match. Therefore, coaches and conditioning specialists are required to apply more sport specific knowledge in planning training programmes that allow for optimal preparation for competition, considering physical profile, technical performance and match demands. The aims of this study was firstly, to examine if there are position-specific differences in the morphological characteristics of South African sub-elite female soccer players. Secondly, to evaluate the effect of aerobic and anaerobic fatigue on the technical skills performance of sub-elite female soccer players. Thirdly, to assess the internal and external match demands of sub-elite female soccer players within and between matches in a tournament.

Chapter 1 provided a brief introduction and problem statement that underlies the research questions of the study, the objectives and the related hypotheses of the study, as well as the structure of the thesis and a schematic conceptualised representation of the larger project under which the study was conducted. Through this chapter, it was acknowledged that limited information is available on female soccer players competing on sub-elite level and posed that further research was needed to investigate the morphological and physical characteristics of players on this level. It was also recognised that research investigating the effect of fatigue on technical skill performance and also its influence on match demands within and throughout a tournament is lacking. Sport scientists and conditioning specialist can benefit from these results in prescribing position specific training programmes for optimum performance within matches. The thesis is submitted in article format and consists of an introduction (Chapter 1), literature review (Chapter 2), three scientific research articles (Chapters 3, 4, and 5 respectively) and a summary (Chapter 6).

Chapter 2 consisted of a literature review titled: "Match play analysis, anthropometric measurements and physical profiles of female soccer players." The purpose of this review was firstly to explore current literature pertaining to the anthropometric profile, aerobic and anaerobic fitness qualities and technical skill characteristics of female soccer players. Part of the first aim was further to describe the relationship between some of these variables and also to review positional differences regarding these variables. The second aim was to discuss the internal and external match demands placed on female soccer players. Female soccer players now have the opportunity to train and compete in professional settings. As a result, higher expectations are

placed on female players, which in turn led to an increase in the need for specific scientific research towards identifying means for improving player performance. In contrast to male soccer players, limited scientific information is available on female players regarding physical and physiological characteristics, specifically describing different levels of performance. There is also a shortage of literature describing the match demands of female players.

Competing on elite level requires players to possess morphological and physiological characteristics applicable to the sporting code and also playing position. Standing height is crucial in the selection process and values ranging from 161–169 cm were noted for elite female players. Average body mass range from 56–67 kg. Certain anthropometric predispositions exist when analysing positional differences, with goalkeepers being taller, heavier and possessing the longest length and largest breadth measurements. Literature shows that defenders generally have the second highest measurements, although it is not consistently proven across studies, with some reporting the second highest values for forwards. However, previous findings agree that midfielders are the shortest and lightest players with the smallest values recorded for length and breadth measurements. It is evident that taller players are more suitable for defensive positions. The physical characteristics of goalkeepers lend them an advantage in defending the broad area between the goalposts. Likewise, taller defenders would also have a competitive benefit in performing actions such as jumping to gain possession of the ball with their head. An elevated lean body mass could also be beneficial for performing power activities such as jumping and sprinting. The physical traits of midfielders allow them to move more efficiently across the field and serve as a linking role between defence and attack.

An important part of body composition is the amount of body fat (BF) a player possesses. A low BF% is desirable for successful competition, since excess adiposity has a negative influence on performance. The BF% of elite female players range from 18.5–20.6%. Goalkeepers often have the highest BF%, which can possibly be explained by the lower aerobic demand specific to the position and lower energy expenditure during training and competition. Midfielders have the lowest BF%, again due to their positional role of linking the front and the back of the field. It is further noted that mesomorphy is the predominant somatotype component among soccer players, and an important factor for strength. Body types in which a high muscle content is prevalent can be advantageous in soccer due to the high intensity and repetitive type intermittent activity required in matches.

Soccer places diverse physical demands on players and therefore players need a good physical condition to perform optimally. The sport relies predominantly on aerobic metabolism, although

explosive power is often required to win in critical moments in a match. With a game consisting of 90 minutes of play, optimal aerobic fitness is imperative to allow for technical and tactical skills to be used to their full potential throughout a match. Female players typically cover 9–11 km during a match, of which 10–15% of the total distance are covered at high-intensity (HI). Due to expensive equipment and trained personnel being required to perform time-consuming laboratory fitness testing, an alternative is required for the regular assessment of fitness in large groups of players, making the Yo-Yo IR1 a popular test for the assessment of  $\dot{V}O_{2max}$  due to its specificity and practicality for soccer. It has been proven to be a good predictor of elite female soccer players' ability to perform high-intensity running (HIR) throughout matches. The  $\dot{V}O_{2max}$  of elite female players range between 48.7–56.8 ml/kg/min, with the highest values recorded among midfielders, followed by forwards. Furthermore, the anaerobic energy system must also be well-trained to perform HI activities and recover optimally between burst of anaerobic activity. Short-phases of repeated-sprint activity may be required on many occasions during a match and may be critical to the end result of a match.

Soccer is further characterised as a free-flowing game requiring the execution of many aspects of skill in a dynamic context. Passing, controlling and shooting are essential skills necessary in soccer, with dribbling and short passes being the most frequently performed skills observed in matches. There is a shortage of valid and reliable technical skills tests due to the complex nature of soccer skills and replicating it in a controlled laboratory setting. The Loughborough Soccer Passing Test (LSPT) has been proven to be a valid and reliable method for evaluating the technical skill performance in female soccer players, and assess the multifaceted aspects of soccer, including passing, dribbling, controlling, shooting and decision-making. It is also of importance to understand the effect of aerobic- and anaerobic fatigue on technical performance, while limited previous research evaluated these relationships. Studies have noted that aerobic or anaerobic fatigue would hinder technical skill performance, measuring decreases in passing and shooting ability following different forms of match-related fatigue. Studies concluded that technical training should be conducted under conditions of fatigue to ensure players can maintain accurate skill execution when fatigued in a match.

Finally, an understanding of the internal and external match demands placed upon female players are important to assist coaches and conditioning specialist in planning training programmes that will lead to optimal performance in matches. The use of Global Positioning System (GPS) technology now allows for a greater comprehensive study of locomotor patterns, permits real-time data collection and provides information pertaining to position, displacement, velocity and

acceleration of players. Although no standardised velocity thresholds currently exists for quantifying female soccer matches, the following zones have been used in female soccer: standing and walking (0.0–1.6 m/s), jogging (1.7–2.2 m/s), low-intensity running (LIR) (2.3–3.3 m/s), moderate-intensity running (MIR) (3.4–4.3 m/s), HIR (4.4–5.6 m/s) and sprinting (>5.6 m/s). A large proportion of a match consists of walking or jogging, therefore it is important to determine the pattern of HI work performed. Female players spend around 7.5% and 2.5% respectively at HIR and sprinting during a match. What is evident is that significant reductions are noted in HI movements towards the last part of a match. Work rate ranges between 108–119 m/min for elite female players, and distinctions are clear between playing positions, with midfielders and forwards achieving a higher work rate. Player load is another component to consider when analysing the match demands of players and is a representation of total body load. Player load consists of high- and low-intensity movements or actions such as jumping, tackling, collisions, accelerations, decelerations, passing, shooting, sideways and backward running. It also differs between playing positions. Furthermore, player load is largely related to a player's physiological and perceptual responses to a training stimulus.

When considering the role of fatigue in soccer matches, studies report a decrease in total distance and distances covered in different velocity zones from the first to the second half of a match. The decline in HIR at the end of a match is related to fatigue influencing performance negatively. However, distance covered by means of sprinting often remains similar or does not decrease significantly from the first to the second half and may be due to a decline in HIR and subsequent increase in low-intensity activity, allowing for more recovery opportunities. On the other hand, research shows that players possibly employ pacing strategies, especially players completing a full match, which involves a progressive decline in running intensity throughout a match to reserve energy for periods of high-intensity activity. In addition, evidence suggests that multiple matches during a field sport tournament has an influential role on exercise intensity and consequently leads to accumulated fatigue. The players' ability to maintain exercise intensity throughout a tournament could be of importance for the outcome of a match. Appropriate recovery interventions in competitive tournaments and between matches is therefore important to continually perform at optimal level.

This review consequently indicated that optimal performance in female soccer involves a myriad of factors, whereby an understanding of the morphological profile of players is equally important to being knowledgeable of physical and technical performance requirements. Furthermore, analysis of the internal and external match demands seems to be an emerging topic receiving more attention in current research. This has implications for more precise training prescription

and evaluation. Given the importance of monitoring the training and match performance of players in order to maximise performance, better informed decisions can be made in the planning of training programmes leading to improvement in the performance of female soccer players.

Chapter 3 consisted of the first research article, which was compiled in accordance with the guidelines of the *Women in Sport and Physical Activity Journal* and titled: "Comparison of the morphological characteristics of sub-elite female soccer players according to playing position", by Strauss, Sparks and Pienaar. The main aim of this article was to examine if there are position-specific differences in the morphological characteristics of South African sub-elite female soccer players. A secondary aim was to utilise the morphological characteristics of South African sub-elite female soccer players to establish the foundation for a database designed to create normative standards for female soccer players. Goalkeepers were the only players who differed ( $p \leq 0.05$ ) from the other playing positions regarding morphological characteristics. Goalkeepers were the tallest ( $166.2 \pm 8.4$  cm), heaviest ( $66.5 \pm 5.1$  kg) and possessed the largest anthropometric measurements, lending them a greater advantage in defending the goal area. Differences ( $p \leq 0.05$ ) between the goalkeepers and outfield playing positions were evident in the skinfold measurements of the triceps and supraspinale, the breadth measurements of the wrist and femur, the girth measurements of the relaxed arm, flexed arm, waist, gluteal and calf and the length measurements of the acromiale-radiale, radiale-styilion, midstylium-dactylium and the foot. In contrast, the midfielders were the shortest ( $158.7 \pm 6.1$  cm) and lightest ( $55.0 \pm 8.4$  kg) players, and further generally had the smallest breadth, girth and length measurements, efficiently equipping them with the ability to fulfil a linking role between the front and back players. These results correspond with certain trends in previous research findings on female players. Body fat percentage ( $20.8 \pm 5.7\%$ ) was within the range previously reported for female players, with goalkeepers possessing the highest BF% values. Finally, a balanced endomorphic (4.0–2.4–2.1) body type was evident among the players. Neither BF% nor body type differed between playing positions. The results indicate that significant positional differences exist in certain morphological features. The results furthermore contribute to the limited research available female soccer players competing on sub-elite level.

Chapter 4 presented the second research article that was compiled in accordance with the guidelines of the *Journal of Sports Science and Medicine* and titled: "The effect of exercise-induced fatigue on the technical skill performance of sub-elite female soccer players", by Strauss, Sparks and Pienaar. The aim of this article was to evaluate the effect of aerobic and anaerobic fatigue on the technical skill performance of sub-elite female soccer players. The secondary aim was to determine the aerobic and anaerobic fitness characteristics of sub-elite female soccer

players. The article succeeded to determine that physical fatigue had a detrimental effect on short-passing ability. Players achieved a mean distance of 560 m in the Yo-Yo IR1. A mean distance of 614 m was achieved in the RSA test. Peak HR was slightly higher following the Yo-Yo IR1 (190 bpm) than after the RSA (186 bpm) tests. Blood lactate measured was higher after the RSA test than after the Yo-Yo IR1. The RPE (7.1) following the fatiguing tests was similar. Furthermore, an average  $\dot{V}O_{2\max}$  of 41.1 mL/kg/min was recorded. The deteriorated performance in the LSPT following the Yo-Yo IR1 and the RSA tests was proven by the increase in passing time (1.4% and 3.7%), penalty time (32.6%,  $p < 0.01$ ; and 20.4%,  $p < 0.05$ ) and total time (10.1%,  $p < 0.01$ ; and 8.5%,  $p < 0.05$ ) respectively. Due to the time limit imposed on the LSPT, players appeared to have sacrificed accuracy of passes in order to maintain the speed of completing the test. Aerobic fatigue influenced technical performance more than anaerobic fatigue, which can be justified by the low aerobic fitness levels of the players.

Chapter 5 contains the third research article that was compiled in accordance with the guidelines of the *Journal of Strength and Conditioning Research* and titled: "The use of GPS analysis to quantify the internal and external match demands of sub-elite female soccer players during a tournament", by Strauss, Sparks and Pienaar. The aim of this article was to assess the internal and external match demands of sub-elite female soccer players during a tournament. The secondary aim was to describe the magnitude of change of these variables within and between matches over the course of a tournament to determine the effect of player fatigue. The results of this article showed that significant ( $p \leq 0.05$ ) differences exist in the internal and external match demands of university-level female soccer players within and between matches in a tournament. The study further showed significant positional differences in those demands. Total distance covered averaged 5917 km. Players spent 42% standing/walking, 11% jogging, 23% LIR, 11% MIR, 5% HIR and 1% sprinting. Within match comparisons showed that relative distance, LIA and HIA decreased from the first to the second half with possibly trivial to likely small changes. Player load decreased ( $p \leq 0.05$ ) in the second half (ES: 0.4). The decrease in relative total distance can be explained by the 7% decrease in LIA and a 6% decrease in HIA across match halves. The higher player load during the first half further suggests more movement activities performed in comparison to the second half. The reduction in movement activities during the second half can be the result of fatigue experienced following the first half. It is also possible that a particular strategy was employed by the players through exerting more intense efforts during the first half in an attempt to physically challenge and exhaust the opposition players to have a competitive advantage during the second half. Small to large differences in variables were observed throughout the tournament. Comparisons between matches generally indicated the highest performance during match 2, from where gradual reductions in performance variables were

measured towards match 5. The competition load may have impaired the players' performance due to insufficient recovery between matches, leading to shorter distances covered in total and within each velocity zone, specifically at HIA.

Regarding playing positions, the midfielders achieved the greatest absolute and relative total distance and defenders the least. Defenders covered less ( $p \leq 0.05$ ) relative distance and LIA per minute of play compared to midfielders. This greater total distance covered by midfielders was predominantly from more LIA per minute of play. Midfielders fulfil a linking role between the front and back players, which can justify the higher work rate among players in this position. Forwards covered the greatest distance at HIA compared to midfielders and defenders. In addition to distances measured at different intensities, player load proved to differ between playing positions, with midfielders achieving the highest player load per minute of play. The higher level of manoeuvrability required by midfielders in performing their positional tasks could result in a greater player load due to performing more movement activities.

## 6.2 Conclusions

The conclusions drawn from this research are presented in accordance with the set hypotheses from Chapter 1:

**Hypothesis 1:** *There will be significant ( $p \leq 0.05$ ) position-specific differences in the morphological profile of South African sub-elite female soccer players.*

Each positional role was characterised by a different profile. Fifteen out of twenty-one anthropometric components showed significant ( $p \leq 0.05$ ) differences between playing positions. Differences ( $p \leq 0.05$ ) were noted when the goalkeepers were compared to the outfield playing positions. However, the outfield positions did not differ when compared against one another. Except for higher BF% values among goalkeepers, it was not a distinguishing factor for the outfield playing positions with no significant ( $p \leq 0.05$ ) differences between any of the playing positions. No significant ( $p \leq 0.05$ ) positional differences were found in somatotype characteristics. To conclude, although the morphological profile of goalkeepers differed significantly from the other playing positions, no significant differences were found between outfield players. Hypothesis 1 is therefore *partially accepted*.

**Hypothesis 2:** *Aerobic and anaerobic fatigue will have a significant ( $p \leq 0.05$ ) negative effect on the technical skill performance of sub-elite female soccer players.*

Physical fatigue had a detrimental ( $p \leq 0.05$ ) effect on short-passing ability. In particular, penalty time increased following the Yo-Yo IR1 ( $p < 0.001$ ; 32.6%) and the RSA test ( $p = 0.01$ ; 20.4%). This was evident in the decrease in precision of passes and ultimately resulted in a significant ( $p \leq 0.05$ ) deterioration in the total performance time following both fatiguing exercises. It was evident that the performance detriment in motor control during both post-tests was due to the aerobic and anaerobic fatigue experienced.

Hypothesis 2 is therefore *accepted*.

**Hypothesis 3:** *The internal and external match demands of sub-elite female soccer players will differ significantly ( $p \leq 0.05$ ) within and between matches in a tournament.*

Significant ( $p \leq 0.05$ ) differences in the internal and external match demands of university-level female soccer players exist between matches in a tournament. Total distance within matches decreased ( $p \leq 0.05$ ) with 11% from the first to the second half. Player load also decreased ( $p \leq 0.05$ ) from the first to the second half (ES: 0.4). Possibly trivial to likely small changes were observed for relative distance, LIA and HIA during the second half, attributable to fatigue accumulated during the first half. Throughout the tournament, the largest magnitude of change was noted with a large effect (ES: -1.2) in relative distance covered between match 2 and 5. Evidence suggests that accumulated fatigue experienced throughout a tournament will have a negative effect on match performance.

Hypothesis 3 is therefore *accepted*.

This thesis aimed to investigate the physical and physiological characteristics of sub-elite female soccer players and performance during competitive match play. This is the first study of this magnitude in South Africa and the African continent. This is also the first study on female soccer players in Africa that analysed the effect of aerobic and anaerobic fatigue on the performance of technical skills. An abundance of literature is available on male soccer players of different competitive standard investigating these variables and effects, although less is known about female soccer players, particularly those participating on sub-elite level. In general, literature available on female soccer players places emphasis on elite players, leaving a vast area for further contribution to the field regarding players competing on a different level. Further, what make this study unique, are the distinctions that were made between different playing positions based on most of the variables. It is well established in male soccer that morphological characteristics have an influence on team performance, serving as a guideline for the

identification and selection of talented players for specific positions. Goalkeepers are classified as the taller and heavier players, followed by defenders and forwards. Alternatively, midfielders tend to be the shortest and lightest among the team positions. What was found in this study is that significant differences were only noted between goalkeepers and the other outfield playing positions, while the outfield positions displayed relatively similar traits in general. More evidence pertaining to morphological characteristics and the classification of positional distinctions, can contribute to female soccer and the enhancement of performance within specific positions, and prove that these distinct characteristics become more specific as the competitive level increases.

Apart from positional distinctions regarding morphological features, this study contributes to a better understanding of the influence of fatigue on technical skill performance. In female soccer, the LSPT has not received much attention in research, therefore this study contributes to the very limited information available on female players performing the LSPT. Furthermore, researchers face a challenge to examine the effect of fatigue on the performance of technical skills during a match due to numerous reasons. The researchers of this study sought it relevant to use a soccer-specific technical skill test, such as the LSPT, and assess the effect of fatigue on technical skill performance. Evidence is clear that both aerobic and anaerobic fatigue would have a negative effect on technical skill performance, although aerobic fatigue would have a greater negative influence. What can be concluded is that all aspects that form part of the LSPT decrease due to fatigue. This leads to the conclusion that dribbling, passing accuracy, controlling the ball and the ability to make decisions will be hindered by fatigue. This will ultimately lead to a reduction in performance in a match, which could affect the outcome of the match.

It is possible that not only are players participating on a high level because of their technical and tactical skills, but that their high physical performance allows them to compete at a higher level. Currently, very limited research on match assessment of the movement profile of female soccer players using GPS analysis exists. This is also the first study that investigated the match-to-match variations in internal and external match demands during a week-long soccer tournament. Within and between match variations in absolute and relative total distance, player load, and movement intensities are presumably the result of acute and accumulated fatigue experienced by players, and inadequate recovery between matches throughout the tournament. As the tournament progressed, high-intensity activities decreased, suggesting that fatigue had an influential role on match performance. As seen from chapter 4 the LSPT performance showed a greater decrease after the aerobic test which could be due to the lower aerobic conditioning of the players in this study compared to previous studies. These results together with the results from chapter 5 pertaining to match and tournament fatigue suggest that by improving aerobic fitness, players may recover

quicker following acute bouts of maximal sprint efforts, cover greater distances during a match and be able to maintain their technical skills and mental concentration more efficiently towards the latter part of a match. Higher aerobic fitness and the use of specific recovery interventions between matches in such a tournament may also provide the players with the capacity to maintain performance as the tournament progresses.

The findings of this study suggest that position specific training interventions can be used to optimise the performance of players and meet the demands of each playing position through aerobic and technical skills training. In conclusion, the importance of physical conditioning of female soccer players along with improving their technical skill performance should be emphasised in training programmes to combat the effect of fatigue on technical skill and match performance.

The unique contribution of this thesis to the current available literature and knowledge in this field can be summarised as follows:

- Understanding positional differences in morphological characteristics can assist sport scientists and conditioning specialists in designing position-specific based training programmes based on physical traits, which can ultimately lead to improved performance and participation on a higher level.
- The greater negative influence of aerobic fatigue on technical skill performance emphasises the importance of incorporating HI aerobic exercise into training programmes.
- The authors established that a week-long tournament leads to reductions in overall performance towards the end of the tournament, suggesting that accumulated fatigue during and following each match leads to further reductions as the tournament progresses.

### **6.3 Limitations and Recommendations**

Although this study provided valuable information pertaining to the profile and performance of sub-elite female soccer players, several limitations of the study should, however, be considered, along with recommendations for future researchers who wish to focus on this area of study:

- The participants in this study were not randomly selected according to the population representative of players competing on sub-elite level in South Africa. Future studies should therefore include players participating on sub-elite level that would be representative of the entire population in the country.
- Arousal level and mental fatigue could explain lower performance in the LSPT following fatiguing exercises. Studies involving the cognitive assessment of players following fatiguing exercises could therefore contribute to the current findings.

- The results of the present study relating to match demands must be interpreted with caution, since a small sample size of sub-elite female soccer players were used. Future research should for this reason attempt to use larger sample sizes, specifically if positional comparisons are made.
- Future research on sub-elite players competing in a tournament of this nature should attempt to assess all the players from the participating teams, from which results can be compared based on final team ranking at the end of the tournament.
- Due to the expensive nature of GPS devices, only the starting ten players could be fitted with devices. Data on substitution players could therefore not be collected. Tactical substitutions of players have been proven effective in other team field sports, indicating differences in movement intensities compared to players who have played a full match. The influential role that substituting players could have on a match and differences in movement intensities compared to full-match players is therefore a future research possibility.

#### **6.4 Future research**

For future research we would like to recommend investigating the following:

- To examine whether implementing a programme designed to fatigue players before technical skills training is performed will improve the technical performance of these players under fatigued states.
- To investigate whether different recovery techniques will improve the match performance of soccer players during a tournament.

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# ANNEXURES

Annexure A: Certificate of Ethics Approval

Annexure B: Informed consent form

Annexure C: Demographic and general information questionnaire

Annexure D: Forms for the collection of data regarding anthropometric, physical fitness and technical skills

Annexure E: Instructions for authors from the *Women in Sport and Physical Activity Journal*, the *Journal of Sports Science and Medicine*, and the *Journal of Strength and Conditioning Research*.

Annexure F: Authorization letter for reproduction of Loughborough Soccer Passing Test figure

Annexure G: Proof of language editing

Annexure H: Description of testing procedures



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21 September 2015

Dr M Sparks  
PhASRec

Dear Dr Sparks

## **HREC APPROVAL OF YOUR APPLICATION**

**Ethics number: NWU-00055-15-S1**

Kindly use the ethics reference number provided above in all correspondence or documents submitted to the Health Research Ethics Committee (HREC) secretariat.

**Project title: Anthropometric profile, selected physical parameters, technical skills and match demands of university-level female soccer players**

**Project leader/supervisor: Dr M Sparks**

**Student: A Strauss**

**Application type: Full Single**

**Risk level descriptor: Minimal**

You are kindly informed that at the meeting held on 17/04/2015 of the HREC, Faculty of Health Sciences, the aforementioned was approved. The period of approval for this project is from 21/09/2015 to 31/12/2017.

### **After ethical review:**

Translation of the informed consent document to the language's applicable to the study participants should be submitted to the HREC (if applicable).

The HREC requires immediate reporting of any aspects that warrants a change of ethical approval. Any amendments, extensions or other modifications to the protocol or other associated documentation must be submitted to the HREC prior to implementing these changes. Any adverse/unexpected/unforeseen events or incidents must be reported on either an adverse event report form or incident report form.

A progress report should be submitted within one year of approval of this study and before the year has expired, to ensure timely renewal of the study. A final report must be provided at completion of the study or the HREC must be notified if the study is temporarily suspended or terminated. The progress report template is obtainable from Carolien van Zyl at

[Carolien.VanZyl@nwu.ac.za](mailto:Carolien.VanZyl@nwu.ac.za). Annually a number of projects may be randomly selected for an external audit.

Please note that the HREC has the prerogative and authority to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.

Please note that for any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the HREC. Ethics approval is required BEFORE approval can be obtained from these authorities.

The HREC complies with the South African National Health Act 61 (2003), the regulations on Research with Human Participants of 2014 of the Department of Health and Principles, the Declaration of Helsinki, 2013, the Belmont Report and the Ethics in Health Research: Principles, Structures and Processes (SANS document).

We wish you the best as you conduct your research. If you have any questions or need further assistance, please contact the Ethics Office at [Carolien.VanZyl@nwu.ac.za](mailto:Carolien.VanZyl@nwu.ac.za) or 018 299 2089.

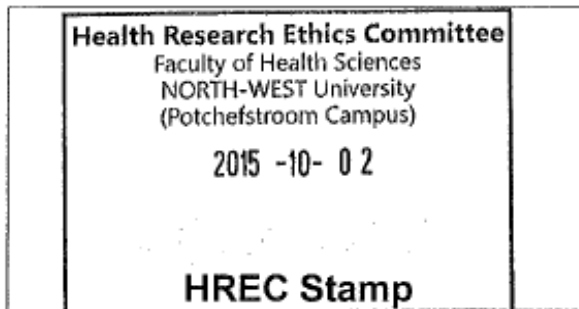
Yours sincerely



Prof Minnie Greeff  
HREC Chairperson

Current details: (13210572) C:\Users\13210572\Documents\HREC\HREC - Applications\2015 Applications\Applications 03 - 17 April 2015\NWU-00055-15-S1 (M Sparks-A Strauss)\NWU-00055-15-S1 (M Sparks-A Strauss) - AL\NWU-00055-15-S1 (M Sparks-A Strauss) - AL.docm  
21 September 2015

File reference: 9.1.5.3



## **PARTICIPANT INFORMATION LEAFLET AND CONSENT FORM FOR UNIVERSITY-LEVEL FEMALE SOCCER PLAYERS**

**TITLE OF THE RESEARCH PROJECT: INVESTIGATING PERFORMANCE INDICATORS AND INJURY RISK FACTORS FOR THE DEVELOPMENT AND PERFORMANCE OF FEMALE SOCCER PLAYERS**

**REFERENCE NUMBERS: NWU-00055-15-A1**

**PRINCIPAL INVESTIGATOR: DR. MARTINIQUE SPARKS**

**ADDRESS: BUILDING K3, CNR OF THABO MBEKI & MEYER STR,  
POTCHEFSTROOM**

**CONTACT NUMBER: 018 299 1770**

You are being invited to take part in a research project. Please take some time to read the information presented here, which will explain the details of this project. Please ask the researcher any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how you could be involved. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the **Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00055-15-A1)** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki and the ethical guidelines of the National Health Research Ethics Council. It might be necessary for the research ethics committee members or relevant authorities to inspect the research records.

**What is this research study all about?**

- *This study will be conducted at your home training field at the university and at the annual University Sports South Africa (USSA) tournament and will involve us measuring your body composition (eg. Mass, skinfolds etc.), flexibility as well as you performing two fitness tests, a speed test, a stability test and a skills test with experienced health researchers trained in Sport science. You will also be asked to complete two psychological questionnaires and an injury questionnaire. We will also monitor and analyse all of your matches during the USSA tournament. Thirty-eight participants will be included in this study.*
- *The objectives of this research are:*
  - *to determine the anthropometric profile according to player position of university-level female soccer players, thus developing a player profile for each position describing body mass, height, stature and fat percentage;*
  - *to determine the relationship between technical skills and the aerobic- and anaerobic fitness characteristics of university-level female soccer players, thus determining whether your technical skill performance will be influenced by your level of aerobic- and anaerobic fitness;*
  - *to determine the position specific internal and external match demands of university-level female soccer players by making use of global positioning system (GPS) analyses, thus using GPS technology to provide information such as your heart rate and the amount of time you spend at different intensity efforts performing activities such as standing, walking, jogging and running.*
  - *to determine the effect of an aerobic fatiguing test on the salivary cortisol levels and the psychological state of amateur female soccer players;*
  - *to determine the effect of an anaerobic fatiguing test on salivary cortisol levels and the psychological state of amateur female soccer players;*
  - *to determine the effects of the match-outcome (win/lose) and fatigue as a result of a soccer match on salivary cortisol levels and the psychological state of amateur female soccer players*
  - *to determine the injury history and incidence in university level African female soccer players.*
  - *to determine the intrinsic risk factors associated with lower limb injuries in university level African female soccer players.*

**Why have you been invited to participate?**

- *You have been invited to participate because you are female and represent your university in soccer*
- *You have also complied with the following inclusion criteria: you are currently injury free and you are part of the USSA squad.*
- *You will be excluded if: you become injured or ill at any time during the project or if we are not able to test you 2 weeks before the USSA championship starts.*

**What will your responsibilities be?**

- *You will be expected to:*
  - *Complete the informed consent form before the first day of testing. Informed consent will be obtained by an independent person not directly involved in the study.*
  - *Complete a questionnaire that pertains to your demographic information, playing and injury history on the first day of testing.*

- You will be instructed not to engage in strenuous exercise for at least 48 hours before the fitness testing session. The research team will guide the coaches towards which activities will be allowed to engage in before testing. The research team will also consult with coaches beforehand to inform them of the intended dates of testing, so that they can plan their training program in such a way to accommodate the testing and necessary rest before testing commences.
- Conduct assessments for body composition. Various measurements will be taken using a skinfold calliper by Level 2 International Society for the Advancement of Kinanthropometry (ISAK) certified anthropometrists at a private designated testing area. This will include measurements of body mass, stature, skinfolds, breadths, girths and lengths and will require you to wear minimal clothing. You are allowed to strip down to as much clothing as is comfortable to you. These measurements will be taken at a private enclosed location. The flexibility in your legs and ankles will also be tested in this area.
- While you wait to be measured an injury history questionnaire will be completed for you by a Biokineticist. You will also be asked to complete two psychological questionnaires and provide a saliva sample before the onset of the physical testing
- Conduct tests for speed (40 m sprint test) and stability. The tests will be explained to you after which you will engage in a general warm-up of 10-15 min consisting of low-intensity jogging followed by static and dynamic stretching. You will then conduct the tests for speed and stability. You will be allowed to wear your soccer boots to complete these tests.
- You will then perform the technical skills test (consisting of dribbling, passing and control), followed by the aerobic fitness test (Yo-Yo Intermittent recovery test level 1 (Yo-Yo IR1)). During the execution of the aerobic fitness test you will be asked to run while being fitted with a portable gas analyser apparatus to measure your expired air as you run. This will require a harness to be fitted to your chest as well as a mask over your head and face. The mask will not hinder your breathing and you will be able to breathe normally. There will also be a heart rate belt fitted across your chest to monitor your heart rate during the test. After the completion of the aerobic fitness test, you will rate how tired you are and a blood lactate concentration [LA] will be taken from the fingertip of the left hand by means of a finger prick test. After blood sampling, you will again complete the skills test. You will not be allowed to recover between the technical skills test and the aerobic test, because we want to examine the effect of exhaustion on soccer skill performance. After the final test you will complete two psychological questionnaires for a second time and thirty minutes after the last test another saliva sample will be taken.
- Engage in explosive power (Vertical jump) test, technical skills and anaerobic fitness tests on the second day of testing. The tests will be explained to you after which you will perform general warm-up of 10–15 min consisting of low-intensity jogging followed by static and dynamic stretching. You will also be asked to complete two psychological questionnaires and provide a saliva sample before the onset of the physical testing. You will then conduct the explosive power test, technical skills test (consisting of dribbling, passing and control) and the anaerobic fitness test (repeated sprint ability test (RSA)). During the execution of the repeated sprint ability test, you will be required to sprint shuttles of 5 meters over a distance of 20 meters. After the completion of the anaerobic fitness test, you will rate how tired you are and a blood

*lactate concentration [LA] will be taken from the fingertip of the left hand by means of a finger prick test. After blood sampling, you will again complete the skills test. You will not be allowed to recover between the technical skills test and the anaerobic test, because we want to examine the effect of exhaustion on soccer skill performance. After the final test you will complete two psychological questionnaires for a second time and thirty minutes after the last test another saliva sample will be taken.*

- *Be assessed at the USSA championship during the matches. You will be asked to wear a GPS sampling unit. This is a vest that is worn underneath your playing shirt, it is lightweight and will not obstruct your play in any way. Again a heart rate belt will be fitted across your chest to monitor your heart rate during the match. Before commencement of the tournament, you will be allowed to wear the GPS harness with the unit and heart rate (HR) transmitter belts during a practice session to familiarize yourself with units, to ensure you do not feel uncomfortable on the first day of the tournament.*
- *During the tournament saliva samples will be collected and the STAI and POMS questionnaire completed 1 hour before- and 30 minutes after the match, independent of the time of day that the match will take place. Following the soccer match, players will be instructed to indicate their RPE and complete the two questionnaires. Thirty minutes after the match the saliva samples will be collected.*

#### **Will you benefit from taking part in this research?**

- *The direct benefits for you as a participant will be that you will have access to your results by means of a personal report provided to you within 4 weeks after the final testing period. In the case of any immediate or unanticipated incidental findings occurring during the time of testing, you will be informed. The data gathered could enable you as player and your coach to compile specific and effective conditioning programs for the different player positions (attackers, midfielders and defenders) that will prepare you for the demands of soccer matches, consequently resulting in an improvement of performance. You could also benefit in terms of your own health by using results provided to you to improve your body composition and physical condition.*
- *The indirect benefit will be a broadening of specialist sport science knowledge with regards to female soccer, which can be transferred to the larger soccer community. This includes knowledge in the field of physical and physiological profiles and match demands of university level female soccer players. Workshops will be held after the completion of the project to empower not only university-level coaches, but also developing coaches to construct effective training programs for their female soccer teams.*
- *Scientists will gain understanding into the different intrinsic risk factors that are associated with lower limb injuries and how to minimize such injuries in future.*
- *Two Biokineticists will also travel with your team during the tournament to assist with strapping and massaging before and after matches.*

#### **Are there risks involved in your taking part in this research?**

- *The risks in this study are:*
  - *Physical discomfort: No severe physical stress beyond the risk encountered in normal life and everyday training are anticipated. All the skills and fitness tests are movements that you regularly do in your training program. You will be thoroughly warmed up before taking part in any of these tests. Should you*

*experience pain or injury at any point you can stop the test and the physiotherapist or team doctor will first be allowed to examine you and assess your injury or discomfort.*

- *Physical exhaustion: The Yo-Yo IR1 test and RSA test are maximal performance tests that need to be done until complete exhaustion. However, you are free to stop the test if you experience any light headedness, shortness of breath or headaches. An Automated External defibrillator (AED) with a qualified operator will also be at all testing opportunities if the need to use the apparatus arises.*
  - *Social stress: No negative influence due to the presence of other players and the coaching staff are anticipated, due to you being accustomed to participate in a group and in front of the coaching staff and spectators. A clinical psychological consultant will be available for debriefing in case of any emotional reactions.*
  - *Blood sample collection: Some discomfort might be experienced when the finger prick is done for blood sample collection. The procedure will be thoroughly explained to you and you will be free to withdraw if you are not comfortable with continuing. It will be a single prick on your finger taken by qualified scientists. Extreme pain is not expected. The finger prick test will be done on both the first and second day of testing. The needle of the finger prick apparatus as well as the disposable gloves will immediately be dispelled into an anatomical waste bin after each measurement taken. After a lactate reading is given by the lactate analyser the used blood lactate strips will also be dispelled into the portable biodegradable waist container. All the material will be disposed immediately after the collection of the data. The disposable waist container will be collected by the manufacturer, as per instructions.*
  - *Salivary sample collection: No severe physical stress beyond the risk encountered in normal life and everyday training are anticipated. Saliva will be collected through a plastic straw into a 20 ml collection vial. The saliva sample will only be used to do hormonal analysis; no other analyses will be done.*
  - *Psychological stress: A Sport Psychological Consultant will be available for debriefing in case of any emotional reactions experienced.*
  - *Injury at the championship: You will not be exposed to additional risk due to the research conducted, in addition to that related to playing the game. Trained paramedics arranged by the tournament directors will be present at the tournament in case of any injuries.*
- *The benefits outweighs the risk*

**What will happen in the unlikely event of some form of discomfort occurring as a direct result of your taking part in this research study?**

- *You might feel uncomfortable during the anthropometric measurements where body mass, stature, skinfolds, breadths, girths and lengths will be measured as you will be required to wear minimal clothing and the measurements might result in discomfort. The measurements will be taken by two experienced ISAK Level 2 certified anthropometrists. You will be measured alone in a private designated and enclosed area and will be allowed to strip down to as much clothing as is comfortable for you. Testing will be done taking your privacy into consideration*
- *Should you have the need for further discussions after the physical or psychological discomfort which might be experienced during the testing*

*procedures, an opportunity will be arranged for you to consult with the team doctor, physiotherapist or clinical psychologist.*

**Who will have access to the data?**

- *Anonymity will be partial to protect you as individual. Confidentiality will be ensured by assigning a code to you only known by the researchers. Complete confidentiality cannot be ensured, as the research will be conducted in a group setting and the researchers cannot ensure confidentiality by other group members who might disclose information outside the research setting. In the final dataset it will not be possible to identify you. Reporting of findings will be anonymous and confidential by not using any individual identifiers in any publications resulting from this study. Only the researchers involved in this study will have access to the data obtained.*

**What will happen with the data/samples?**

- *This is a once off collection that will only take place during 2015 and the data will be fully analysed here in South Africa by the Statistical Consultation Services of the NWU.*
- *The hard copies of the data recorded on the first three testing procedures will be stored for a minimum of 7 years in a secure safe in the project leader's office, accessible only by the primary researchers, after which it will be destroyed by means of a paper shredder. The electronic data recorded by the GPS units and heart rate monitors will be downloaded to a password protected personal laptop immediately after each match and a back-up will be made on a compact disc (CD) and stored for a minimum of 7 years in a secure safe in the project leader's office, accessible only by the primary researchers, after which it will be erased from the laptop and the CD destroyed.*
- *The salivary samples will only be used for stress hormone analysis and no other analyses will be conducted on those samples. These analyses will be done at a professional laboratory (Ampath), guaranteeing confidentiality.*

**Will you be paid to take part in this study and are there any costs involved?**

No, you will/will not be paid to take part in the study but refreshments will be provided during and after the testing. You will not have any additional travel expenses during the times that this procedure will be conducted, as the first 3 days of testing will be conducted during normal practice times when you will be at the training field. The final testing to be conducted at the USSA tournament will also not lead to any additional travel expenses for you, as these expenses for travel, accommodation and meals will already have been paid for by the respective universities. There will thus be no costs involved for you, if you do take part.

**Is there anything else that you should know or do?**

- You can contact Dr. Martinique Sparks at 018 299 1770 if you have any further queries or encounter any problems.
- You can contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 2089; carolien.vanzyl@nwu.ac.za if you have any concerns or complaints that have not been adequately addressed by the researcher.

- You will receive a copy of this information and consent form for your own records.

**How will you know about the findings?**

- The findings of the research will be shared with you 4 weeks after the final testing period. We will be sharing the findings with you by providing you with a personal report regarding your performance scores. You are welcome to contact us regarding the findings of the research. Findings with regards to the game analyses and playing position profiles will be shared with the coaching staff, however these results will be given as group statistics with no individual players identified.

**Declaration by participant**

By signing below, I ..... agree to take part in a research study titled: Investigating performance indicators and injury risk factors for the development and performance of female soccer players

I declare that:

- I have read this information and consent form and it is written in a language with which I am fluent and comfortable.
- I have had a chance to ask questions to both the person obtaining consent, as well as the researcher and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ..... on (*date*) ..... 20....

.....  
**Signature of participant**

.....  
**Signature of witness**

**Declaration by person obtaining consent**

I (*name*) ..... declare that:

- I explained the information in this document to .....
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use a interpreter.

Signed at (*place*) ..... on (*date*) ..... 20....

**Signature of person obtaining consent**

**Signature of witness**

**Declaration by researcher**

I (*name*) ..... declare that:

- I explained the information in this document to .....
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use a interpreter.

Signed at (*place*) ..... on (*date*) ..... 20....

.....  
**Signature of researcher**

.....  
**Signature of witness**



**Demographic Questionnaire: Soccer Project**

**Date:** \_\_\_\_\_

PLAYER PERSONAL INFORMATION					
PLAYER NAME & SURNAME					
DATE OF BIRTH	year / month / day				
AGE (YEARS)					
CONTACT NUMBER					
NEXT OF KIN					
NEXT OF KIN CONTACT NUMBER					
POSITION	ATTACKER	MIDFIELDER	DEFENDER	GOALKEEPER	
NAME OF CLUB					
JERSEY NUMBER					
YEARS OF PLAYING EXPERIENCE					
YEARS OF PLAYING AT UNIVERSITY/CLUB LEVEL					
RACE	BLACK AFRICAN	INDIAN	COLOURED	CAUCASIAN	OTHER
DATE OF LAST MENARCH					
PRESCRIBED MEDICATION					



NORTH-WEST UNIVERSITY  
YUNIBESITHI YA BOKONE-BOPHIRIMA  
NOORDWES-UNIVERSITEIT  
POTCHEFSTROOM CAMPUS

### SOCCER PROTOCOL

NAME AND SURNAME

--	--	--	--

DATE OF BIRTH

--	--	--	--

POSITION

DEFEND	MIDFIELD	ATTACK	GOAL
--------	----------	--------	------

STATURE (cm)

--

WEIGHT (kg)

--

### BODY COMPOSITION

TEST COMPONENT	1 <sup>ST</sup> READING	2 <sup>ND</sup> READING	MEAN
TRICEPS SKINFOLD (MM)			
SUBSCAPULAR SKINFOLD (MM)			
SUPRASPINALE SKINFOLD (MM)			
ABDOMINAL SKINFOLD (MM)			
FRONT THIGH SKINFOLD (MM)			
MEDIAL CALF SKINFOLD (MM)			
TEST COMPONENT	1 <sup>ST</sup> READING	2 <sup>ND</sup> READING	MEAN
HUMERUS BREADTH (CM)			
WRIST BREADTH (CM)			
FEMUR BREADTH (CM)			
ANKLE BREADTH (CM)			
TEST COMPONENT	1 <sup>ST</sup> READING	2 <sup>ND</sup> READING	MEAN
RELAXED ARM GIRTH (CM)			
FLEXED ARM GIRTH (CM)			
WAIST (MINIMUM) GIRTH (CM)			
GLUTEAL (HIP) GIRTH (CM)			
MID THIGH GIRTH (CM)			
TEST COMPONENT	1 <sup>ST</sup> READING	2 <sup>ND</sup> READING	MEAN
ACROMIALE-RADIALE LENGTH (CM)			
RADIALE-STYLION RADIALE LENGTH (CM)			
MIDSTYLION-DACTYLION (CM)			
FOOT LENGTH (CM)			



**FLEXIBILITY**

- ILIOPSOAS FLEXIBILITY (°)
- QUADRICEPS FLEXIBILITY (°)
- HAMSTRING FLEXIBILITY (°)
- ANKLE FLEXIBILITY (°) (PLANTAR)
- ANKLE FLEXIBILITY (°) (DORSI)
- ANKLE FLEXIBILITY (°) (INVERSION)
- ANKLE FLEXIBILITY (°) (INVERSION)

R	L
R	L
R	L
R	L
R	L
R	L
R	L

**EXPLOSIVE POWER**

- VERTICAL JUMP (cm)
  
- TENDO PEAK POWER (W)
- TENDO SPEED (M/SEC)

PAAL	PAAL	PAAL
REACH	1	2
<b>TOTAL</b>		
1	2	
1	2	

**LOWER LIMB STABILITY**

- CENTRE OF PRESSURE TEST (EYES OPEN)
- CENTRE OF PRESSURE TEST (EYES CLOSED)
- LIMITS OF STABILITY TEST

R	L
R	L
R	L

**SPEED**

- 10m (sec)
- 30m (sec)
- 40m (sec)

1	2
1	2
1	2



**ANAEROBIC POWER**

RAST TEST (sec)

**MAXIMUM POWER:**

**MINIMUM POWER:**

**AVERAGE POWER:**

**FATIGUE INDEX (%):**

HR<sub>MAX</sub> (BPM)

LACTATE (MMOL)

	<b>1.</b>	
	<b>2.</b>	
	<b>3.</b>	
	<b>4.</b>	
	<b>5.</b>	
	<b>6.</b>	

**ANAEROBIC POWER**

YO-YO LEVEL

DISTANCE (m)

HR<sub>MAX</sub> (BPM)

LACTATE (MMOL)

LEVEL
m

**Speed level      Repetitions**

5	1 (40)							
9	1 (80)							
11	1 (120)	2 (160)						
12	1 (200)	2 (240)	3 (280)					
13	1 (320)	2 (360)	3 (400)	4 (440)				
14	1 (480)	2 (520)	3 (560)	4 (600)	5 (640)	6 (680)	7 (720)	8 (760)
15	1 (800)	2 (840)	3 (880)	4 (920)	5 (960)	6 (1000)	7 (1040)	8 (1080)
16	1(1120)	2(1160)	3(1200)	4(1240)	5(1280)	6 (1320)	7 (1360)	8 (1400)
17	1(1440)	2(1480)	3(1520)	4(1560)	5(1600)	6 (1640)	7 (1680)	8 (1720)
18	1(1760)	2(1800)	3(1840)	4(1880)	5(1920)	6 (1960)	7 (2000)	8 (2040)
19	1(2080)	2(2120)	3(2160)	4(2200)	5(2240)	6 (2280)	7 (2320)	8 (2360)
20	1(2400)	2(2440)	3(2480)	4(2520)	5(2560)	6 (2600)	7 (2640)	8 (2680)
21	1(2720)	2(2760)	3(2800)	4(2840)	5(2880)	6 (2920)	7 (2960)	8 (3000)
22	1(3040)	2(3080)	3(3120)	4(3160)	5(3200)	6 (3240)	7 (3280)	8 (3320)
23	1(3360)	2(3400)	3(3440)	4(3480)	5(3520)	6 (3560)	7 (3600)	8 (3640)

## TECHNICAL SKILLS ASSESSMENT DATASHEET

PLAYER NAME AND SURNAME \_\_\_\_\_

DATE \_\_\_\_\_

TEST COMPONENT															
LOUGHBOROUGH SOCCER PASSING TEST (LSPT) <u>PRE- RAST TEST</u>															
PASS															
1		2		3		4		5		6		7		8	
9		10		11		12		13		14		15		16	
TEST COMPONENT								TIME (SEC)							
PASSING TIME															
TOTAL PENALTY TIME															
TOTAL TIME															

TEST COMPONENT															
LOUGHBOROUGH SOCCER PASSING TEST (LSPT) <u>POST- RAST TEST</u>															
PASS															
1		2		3		4		5		6		7		8	
9		10		11		12		13		14		15		16	
TEST COMPONENT								TIME (SEC)							
PASSING TIME															
TOTAL PENALTY TIME															
TOTAL TIME															

P = Perfect score (-1 sec)

T = Target (hitting coloured target area)

MT = Miss target (0.6 x 0.3 m) area (3 sec)

MB = Missing bench completely/ passing to wrong bench (5 sec)

H = Handling the ball (3 sec)

O = Passing from outside of designated area (2 sec)

C = Ball touching any cone (2 sec)

Every second taken over the allocated 43 sec to complete the test (1 sec)

**PLAYER NAME & SURNAME** \_\_\_\_\_  
**DATE** \_\_\_\_\_

TEST COMPONENT															
LOUGHBOROUGH SOCCER PASSING TEST (LSPT) <u>PRE- YO-YO TEST</u>															
PASS															
1		2		3		4		5		6		7		8	
9		10		11		12		13		14		15		16	
TEST COMPONENT								TIME (SEC)							
PASSING TIME															
TOTAL PENALTY TIME															
TOTAL TIME															

TEST COMPONENT															
LOUGHBOROUGH SOCCER PASSING TEST (LSPT) <u>POST- YO-YO TEST</u>															
PASS															
1		2		3		4		5		6		7		8	
9		10		11		12		13		14		15		16	
TEST COMPONENT								TIME (SEC)							
PASSING TIME															
TOTAL PENALTY TIME															
TOTAL TIME															

- P = Perfect score (-1 sec)  
T = Target (hitting coloured target area)  
MT = Miss target (0.6 x 0.3 m) area (3 sec)  
MB = Missing bench completely/ passing to wrong bench (5 sec)  
H = Handling the ball (3 sec)  
O = Passing from outside of designated area (2 sec)  
C = Ball touching any cone (2 sec)  
Every second taken over the allocated 43 sec to complete the test (1 sec)

## Women in Sport and Physical Activity Journal

### About WSPAJ

*Women in Sport and Physical Activity Journal (WSPAJ)* is a peer-reviewed scholarly journal devoted to advancing the understanding of women in sport and physical activity. *WSPAJ* is the official journal of the Program for the Advancement of Girls and Women in Sport and Physical Activity, housed in the Center for Women's Health and Wellness at the University of North Carolina at Greensboro (learn more [here](#)). This established journal publishes articles related to women's sport and physical activity across the full range of disciplinary perspectives. *WSPAJ* aims to facilitate opportunities for girls and women to enjoy and benefit from sports and other physical activities.

*WSPAJ* presents a body of knowledge readily and conveniently. Original research using varied methodologies as well as theoretical papers, reviews, practical articles, and commentaries will be considered for publication. In addition, *WSPAJ* provides a forum for sharing information and encourages scholars to address issues pertinent to the concerns of women in the sport and physical activity community. The journal also strives toward an international voice, identifying common concerns of women in all countries and working to better communicate among the multicultural women of the world.

*WSPAJ* is available in a digital format, providing online subscribers with the same authoritative content of the print edition but with additional advantages, including the ability to search entire issues in seconds and access to all back issues. The content of the online version of *WSPAJ* is available weeks before the print version arrives by mail, and subscribers can receive the table of contents of each issue by e-mail when a new issue has been published. The online format also allows the submission and use of digital media to better communicate ideas and information.

### Mission

*Women in Sport and Physical Activity Journal*, a peer-reviewed journal, provides a forum for scholarship advancing our understanding of women in sport and physical activity. Published biannually, the journal consists of original research using varied methodologies as well as theoretical papers, reviews, practical articles, and commentaries related to women's sport and physical activity.

### **Authorship Guidelines**

The Journals Division at Human Kinetics adheres to the criteria for authorship as outlined by the International Committee of Medical Journal Editors\*:

Each author should have participated sufficiently in the work to take public responsibility for the content. Authorship credit should be based only on substantial contributions to:

- a. Conception and design, or analysis and interpretation of data; and
- b. Drafting the article or revising it critically for important intellectual content; and
- c. Final approval of the version to be published.

Conditions a, b, and c must all be met. Individuals who do not meet the above criteria may be listed in the acknowledgments section of the manuscript.

\*Uniform requirements for manuscripts submitted to biomedical journals. *New England Journal of Medicine*, 1991, 324, 424–428.

### **Open Access**

Human Kinetics is pleased to allow our authors the option of having their articles published Open Access within *WSPAJ*. In order for an article to be published Open Access, authors must complete and return the Request for Open Access form and provide payment for this option. To request Open Access, click [here](#).

### **Manuscript Guidelines**

*Women in Sport and Physical Activity Journal (WSPAJ)* is a peer-reviewed, scholarly journal devoted to advancing our understanding of women in sport and physical activity. *WSPAJ* publishes scholarly articles related to women's sport and physical activity across the full range of disciplinary perspectives. Original research using varied methodologies as well as theoretical papers, reviews, practical articles, and commentaries will be considered for publication.

### **Style and Format**

In preparing manuscripts for publication in *WSPAJ*, authors should carefully adhere to the guidelines in the *Publication Manual of the American Psychological Association* (6th ed., 2010). All articles must be preceded by an abstract of no more than 250 words. Special attention should be given to the preparation and accuracy of references, and to the absence of sexist and biased language. The manuscript should be double-spaced, including the abstract, references,

and any block quotations. Normally, papers should not exceed a total of 25 pages, including references, tables, and figures.

Manuscripts must not have been published elsewhere or be simultaneously submitted to another journal. The manuscript order should be as follows: (1) blind title page, (2) abstract, (3) manuscript text, (4) references, and (5) tables and figures. For studies involving human participants, the author(s) must include a statement that the research was approved by the appropriate institutional review board and informed consent was obtained.

### **Artwork and Tables**

All artwork must be professionally prepared, with clean, crisp lines. Graphics created on standard computer programs (and submitted in .tif or .jpg formats) will be accepted; freehand or typewritten lettering will not be accepted. If photos are used, they should be clear and show good contrast. Each figure and photo must be properly identified. In graphs, use black and white or gray shading only, no color. Keep labels proportionate with the size of the figures on the journal page. Digital images should be 300 dpi at full size for photos and 600 dpi for line art. Format tables in the table function of your word-processing program rather than aligning columns in text with tabs and spaces or using text boxes.

### **Videos**

Video clips may be submitted to illustrate your manuscript. Upon submission, each digital video file should be designated and uploaded as a “supplementary file.” You also should indicate in the cover letter accompanying your submission that you have submitted a video file. Digital material from a source not original to you as the author must be accompanied by a statement from the copyright holder giving the author permission to publish it; the source and copyright holder must be credited in the manuscript.

Video should be submitted in MPEG-4 (.mp4), Quicktime (.m4v, .mov), or Windows Media (.wmv) format with standard frame sizes of 1920 x 1080 pixels (for high definition) or 720 x 480 pixels (for standard definition) and a frame rate of 30 frames per second. Human Kinetics will inspect all video submissions for quality and technical specifications, and we reserve the right to reject any video submission that does not meet quality standards and specifications.

### **Review**

Please note that a blind review process is used to evaluate manuscripts. As such, any clues to the author’s identity should be eliminated from the manuscript. The first page of the manuscript

must not include author names or affiliations, but it should include the title of the paper and the date of submission. Submissions that do not adhere to these guidelines may be returned to authors.

Manuscripts are read by two reviewers, with the review process taking 8–12 weeks. There are no page charges to contributors.

Please direct all correspondence concerning the journal and manuscript submissions to the *WSPAJ* editorial office: [christinaj@hkusa.com](mailto:christinaj@hkusa.com).

### **Submitting a Manuscript**

Manuscripts should be submitted electronically via ScholarOne (see submission button at the top of this page). ScholarOne manages the electronic transfer of manuscripts throughout the article review process while providing step-by-step instructions and a user-friendly design. Please access the site and follow the directions for authors submitting manuscripts.

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### MISSION

JSSM is an electronic journal aims to present easy access to the scientific knowledge for sport-conscious individuals using contemporary methods. The purpose is to minimise the problems like the delays in publishing process of the articles or to acquire previous issues by drawing advantage from electronic medium. In this context, forming a discussion channel among the researchers would present a further opportunity to address any question or problem immediately. JSSM would also facilitate to display non-conventional materials like video clips, animations, colour photographs, etc.

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### INSTRUCTIONS TO AUTHORS

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**INTRODUCTION**

**METHODS**

**RESULTS**

**DISCUSSION**

**CONCLUSION**

**ACKNOWLEDGMENTS:** Provide information sufficient to identify sources of support, technical assistance, and intellectual contributions not associated with authorship.

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Akova, B., Sürmen-Gür, E., Gür, H., Dirican, M., Sarandöl, E. and Küçükoglu, S. (2001) Exercise-induced oxidative stress and muscular performance in healthy women: role of vitamin E supplementation and endogenous estradiol. *European Journal of Applied Physiology* 84, 141-147.

**Journal article, article not in English:**

Seker-Aygül, Z., Akova, B. and Gür, H. (2001) The relationship of stress and stress management factors with injury in soccer players. *Turkish Journal of Sports Medicine* 36, 71-80. (In Turkish: English abstract).

**Journal article in press:**

Gür, H., Cakin, N., Akova, B., Okay, E. and Küçükoglu, S. (2002) Concentric versus combined concentric- eccentric isokinetic training: Effects on functional capacity and symptoms in patients with osteoarthritis of the knee. *Archives of Physical Medicine and Rehabilitation*, in press.

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Weigand, D.A., Carr, S., Petherick, C. and Taylor, A. (2001) Motivational climate in Sport and Physical Education: The role of significant others. *European Journal of Sports Science (serial online)* 1(4), (13 screens/inclusive page), October. Available from URL: <http://www.humankinetics.com/ejss>

**Abstract:**

Gür, H., Şekir, U., Akova, B. and Küçükoglu, S. (2003) A multi-station proprioceptive exercise program in patients with bilateral knee osteoarthritis: functional capacity, pain and sensorimotor function. 8<sup>th</sup> Annual Congress European College of Sports Science, July 9-12, Salzburg-Austria. Book of Abstract. 404.

**Book:**

Guyton, A.C. and Hall, J.E. (1996) *Textbook of medical physiology*. 9 th edition. W. B. Saunders Company, London.

**Chapter in edited book:**

Wilson, C.H. (1984) Exercise for arthritis. In: *Therapeutic exercise*. Ed: Basmajian, J.V. 4 th edition. Baltimore: Williams and Wilkins. 529-545.

**Thesis:**

Özyener, F. (2000) *Effects of work intensity on dynamics of pulmonary gas exchange during exercise in humans*. Doctoral thesis, University of London, London. 79.

**Thesis not in English:**

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#### MAIN TEXT

The systematic review methodology, the protocol used for identifying studies for inclusion into the review and for assessing the quality of the studies must be given.

#### CONCLUSION

#### ACKNOWLEDGMENT

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#### INTRODUCTION

**CASE REPORT:** A brief case report including history, physical examination and laboratory findings followed by treatment and outcome.

#### DISCUSSION

#### CONCLUSION

#### ACKNOWLEDGMENT

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## Journal of Strength and Conditioning Research

### About the Journal

The editorial mission of *The Journal of Strength and Conditioning Research* (JSCR) is to advance the knowledge about strength and conditioning through research. A unique aspect of this journal is that it includes recommendations for the practical use of research findings. While the journal name identifies strength and conditioning as separate entities, strength is considered a part of conditioning. This journal wishes to promote the publication of peer-reviewed manuscripts which add to our understanding of conditioning and sport through applied exercise science.

### Online Submission and Review System

The Journal of Strength and Conditioning Research (JSCR) is the official research journal of the National Strength and Conditioning Association (NSCA). The JSCR is published monthly. Membership in the NSCA is not a requirement for publication in the journal. JSCR publishes original investigations, reviews, symposia, research notes, and technical and methodological reports contributing to the knowledge about strength and conditioning in sport and exercise. All manuscripts must be original works and present practical applications to the strength and conditioning professional or provide the basis for further applied research in the area. Manuscripts are subjected to a “double blind” peer review by at least two reviewers who are experts in the field. All editorial decisions are final and will be based on the quality, clarity, style, and importance of the submission relative to the goals and objectives of the NSCA and the journal. Tips for writing a manuscript for the JSCR can be found at [http://edmgr.ovid.com/jscr/accounts/Tips\\_for\\_Writing.pdf](http://edmgr.ovid.com/jscr/accounts/Tips_for_Writing.pdf). Please read this document carefully prior to preparation of a manuscript. Manuscripts can be rejected on impact alone as it relates to how the findings impact evidence based practice for strength and conditioning professionals, end users, and clinicians. Thus, it is important authors realize this when submitting manuscripts to the journal.

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## **EDITORIAL MISSION STATEMENT**

The editorial mission of the JSCR, formerly the Journal of Applied Sport Science Research (JASSR), is to advance the knowledge about strength and conditioning through research. Since 1978 the NSCA has attempted to “bridge the gap” from the scientific laboratory to the field practitioner. A unique aspect of this journal is the inclusion of recommendations for the practical use of research findings. While the journal name identifies strength and conditioning as separate entities, strength is considered a part of conditioning. This journal wishes to promote the publication of peer-reviewed manuscripts that add to our understanding of conditioning and sport through applied exercise and sport science. The conditioning process and proper exercise prescription impact a wide range of populations from children to older adults, from youth sport to professional athletes. Understanding the conditioning process and how other practices such as such as nutrition, technology, exercise techniques, and biomechanics support it is important for the practitioner to know.

## **Original Research**

JSCR publishes research on the effects of training programs on physical performance and function to the underlying biological basis for exercise performance as well as research from a number of disciplines attempting to gain insights about sport, sport demands, sport profiles, conditioning, and exercise such as biomechanics, exercise physiology, motor learning, nutrition, and psychology. A primary goal of JSCR is to provide an improved scientific basis for conditioning practices.

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JSCR publishes symposia, brief reviews, technical reports and research notes that are related to the journal’s mission. A symposium is a group of articles by different authors that address an issue from various perspectives. The brief reviews should provide a critical examination of the literature and integrate the results of previous research in an attempt to educate the reader as to the basic and applied aspects of the topic. We are especially interested in applied aspects of the reviewed literature. In addition, the author(s) should have experience and research background in the topic area they are writing about in order to claim expertise in this area of study and give credibility to their recommendations.

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On a separate sheet of paper, the manuscript must have an abstract with a limit of 250 words followed by 3 – 6 key words not used in the title. The abstract should have sentences (no headings) related to the purpose of the study, brief methods, results, conclusions and practical applications.

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The text must contain the following sections with titles in ALL CAPS in this exact order:

A. Introduction. This section is a careful development of the hypotheses of the study leading to the purpose of the investigation. In most cases use no subheadings in this section and try to limit it to 4 – 6 concisely written paragraphs.

B. Methods. Within the METHODS section, the following subheadings are required in the following order: “Experimental Approach to the Problem,” where the author(s) show how their study design will be able to test the hypotheses developed in the introduction and give some basic rationales for the choices made for the independent and dependent variables used in the study; “Subjects,” where the authors include the Institutional Review Board or Ethics Committee approval of their project and appropriate informed consent has been gained. All subject characteristics that are not dependent variables of the study should be included in this section and not in the RESULTS; “Procedures,” in this section the methods used are presented with the concept of “replication of the study” kept in mind. “Statistical Analyses,” here is where you clearly state your statistical approach to the analysis of the data set(s). It is important that you include your alpha level for significance (e.g.,  $P \neq 0.05$ ). Please place your statistical power in the manuscript for the n size used and reliability of the dependent measures with intra-class correlations (ICC Rs). Additional subheadings can be used but should be limited.

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E. Practical Applications. In this section, tell the “coach” or practitioner how your data can be applied and used. It is the distinctive characteristic of the JSCR and supports the mission of “Bridging the Gap” for the NSCA between the laboratory and the field practitioner.

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Below are several examples of references:

### Journal Article

Hartung, GH, Blancq, RJ, Lally, DA, and Krock, LP. Estimation of aerobic capacity from submaximal cycle ergometry in women. *Med Sci Sports Exerc* 27: 452–457, 1995.

### Book

Lohman, TG. *Advances in Body Composition Assessment*. Champaign, IL: Human Kinetics, 1992.

### Chapter in an edited book

Yahara, ML. The shoulder. In: *Clinical Orthopedic Physical Therapy*. J.K. Richardson and Z.A. Iglarsh, eds. Philadelphia: Saunders, 1994. pp. 159–199.

### Software

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### **6. Acknowledgments**

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Ila (fast twitch) and type IIb (fast twitch) forms. The work of Smerdu et. al (AJP 267:C1723, 1994) indicates that type IIb fibers contain type IIx myosin heavy chain (gel electrophoresis fiber typing). For the sake of continuity and to decrease confusion on this point it is recommended that authors use IIx to designate what use to be called IIb fibers. Smerdu, V, Karsch-Mizrachi, I, Campione, M, Leinwand, L, and Schiaffino, S. Type IIx myosin heavy chain transcripts are expressed in type IIb fibers of human skeletal muscle. Am J Physiol 267 (6 Pt 1): C1723–1728, 1994.

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16 March 2018

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I, Assoc Prof Ajmol Ali, provide permission for Anita Strauss and colleagues to use the diagram of the Loughborough Soccer Passing Test (LSPT) that was published in the following reference:

Ali A, Williams C, Hulse MA, Strudwick A, Reddin J, Howarth L, Eldred JE, Hirst M and McGregor SJ (2007). Reliability and validity of two tests of soccer skill. *Journal of Sports Sciences*, 25 (13): 1461-70

Yours faithfully

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24 May 2018

To whom it may concern:

This serves to certify that I, Lydia Searle, performed the copy edit on chapters 1–4 of the document entitled “Anthropometric Profile, Selected Physical Parameters, Technical Skills and Match Demands of University-Level Female Soccer Players”, which was supplied by Mrs Anita Strauss. Regarding Chapter 1 and Chapter 2, references, in-text citation format and language, grammar, punctuation and layout issues were addressed according to the style required by the North-West University, using MSWord Review (Track Changes) function. Chapter 3 and Chapter 4 were edited following the requirements for journal submission.

Yours faithfully,

Lydia Searle

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## DECLARATION OF LANGUAGE EDITING

29 May 2018

To whom it may concern

This is to confirm that I, the undersigned, have language edited Chapter 6 and 7 of the thesis entitled: *Anthropometric profile, selected physical parameters, technical skills and match demands of university-level female soccer players* submitted by Anita Strauss in fulfilment of the requirements for the degree *Doctor of Philosophy in Human Movement Sciences*.

The responsibility of implementing the recommended language changes rests with the author of the dissertation.

Yours truly,

A handwritten signature in black ink, appearing to read 'J Müller'.

Jomone Müller

### **Description of the Yo-Yo Intermittent Recover Level 1 (Yo-Yo IR1) test**

The Yo-Yo IR1, as described by Bangsbo et al. (2006:4), was used to evaluate each player's ability to repeatedly perform intervals over a prolonged period of time and measure each player's maximal oxygen consumption ( $\dot{V}O_{2max}$ ) and maximal heart rate (HR). The test was conducted on a soccer grass field. Cones were used to mark three lines, 20 m and 5 m apart. A commercially available pre-recorded compact disc (CD) was played using a CD player. The players were required to run back and forth between the lines at given speeds controlled by the CD. Upon starting the test, the player stood behind the middle line, facing the last line, and began running 20 m when instructed by the CD. When signalled by the CD, the player turned and returned to the starting point. The player was required to touch the marked lines at either end of the 20 m with one foot when the signal beeped. After each 40 m, the player received a brief 10 sec active recovery period, during which the player had walk back and forth over a 5 m distance. The initial running speed was 10km/h, after which the speed progressively increased. If the line was not reached in time for a beep, a verbal warning was given. The test was terminated if the player failed to reach the line for two consecutive ends within the given time or if the player stopped voluntarily. The last level and number of successfully completed shuttles by each player were recorded for statistical analysis.

### **Description of the repeated-sprint ability (RSA) test**

The RSA test was used to assess the players' anaerobic fitness. The players were instructed not to pace themselves but to perform with maximal effort throughout the test. Six cones were placed 5 m apart in a straight line to cover a total distance of 25 m. The player started the test on the first cone and, upon an auditory signal, sprinted 5 m to the second cone and returned back to the first cone. The player then sprinted 10 m to the third cone and back to the first cone, et cetera. The player continued sprinting back and forth until a period of 30 s has elapsed. After the first bout, the player was given a 35 s rest period before starting the second bout of the activity. The activity was repeated for six times (bouts). The distance covered by each player was approximated to the nearest 2.5 m during each 30 s shuttle and used to determine the average total distance covered by each player (Boddington *et al.*, 2001).

### **Description of the Loughborough Soccer Passing Test (LSPT)**

Four wooden rebound boards are placed in a rectangle on four lines, marking a 12.0 m x 9.5 m grid to the inside of the boards. A coloured target area (red, blue, white and green; dimensions: 0.6 m x 0.3 m) is painted or taped in the middle of each wooden board beforehand, and an aluminium strip (0.1 m x 0.15 m) is attached vertically in the middle of each target area. Yellow lines are used to mark the inner (1 m x 2.5 m) and outer (2.5 m x 4.0 m) rectangles to indicate the passing zone, with coloured cones indicating the different zones. Players are required to perform 16 passes against the coloured target areas in the fastest possible time, and penalty time for inaccurate passes or poor ball control is imposed. One examiner calls out the order of passes, based on the coloured target areas and consisting of eight short and eight long passes, while another examiner records the time taken from the start of the test (first pass) to the last completed pass. The ball is played from within the passing area, and penalty time is awarded for the following errors: missing the bench completely or passing to the wrong bench (5 s); missing the target area (3 s); handling the ball (3 s); passing from outside the designated area (2 s); causing the ball to touch a cone (2 s); and exceeding the allocated 43 seconds to complete the test (1 s awarded for each additional second). However, if the ball hits the aluminium strip, one second is deducted from the total time. Results of the LSPT are typically reported as: time taken to complete the test; penalty time accrued; and total time (Ali *et al.*, 2008).