BODY COMPOSITION AND FUNCTIONAL FITNESS CAPACITY OF YOUNG ACADEMY SOCCER PLAYERS IN SOUTH AFRICA AND ZIMBABWE

BY

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Thesis presented in fulfilment of the requirements for the degree of Masters in Sport Science in the Faculty of Education at Stellenbosch University

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December 2013

DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature

Date: 12 December 2013.

SUMMARY

Talent identification and early selection into a professional soccer academy has been reported to be very important for the long term development of footballing expertise (Le Gall *et al*., 2010). This awareness of the need for early identification of gifted youngsters has led to an increased number of soccer centres of excellence and academies throughout the world. Traditionally, identification and selection of promising individuals into youth soccer academies has been linked to a coach's subjectivity and preconceived image of the player. Once this method is used in isolation it can result in tedious misjudgements in talent identification - hence the emphasis on science-based approaches. Through soccer-specific research, a number of anthropometric and physical parameters have been linked to successful performance in soccer.

The primary aims of the study were to explore the anthropometric, somatotype and functional fitness characteristics of young academy soccer in South Africa and Zimbabwe and to distinguish variables that can be relevant for Talent Identification. The study followed a quantitative non-intervention design with a sample of convenience. A total of 74 young soccer players (Age 15.9±0.81) from South African (n = 41) and Zimbabwean (n = 33) soccer academies were purposively sampled.

The following anthropometric variables were measured following the International Society of the Advancement of Kinanthropometry (ISAK) protocol: body mass and height; skinfolds – (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf); Girths – (arm relaxed, arm flexed and tensed, waist, gluteal, and calf); bone breadths – (biepicondylar humerus and biepicondylar femur). Functional fitness variables that were measured include: lower back muscle flexibility (sit and reach test), upper body flexibility

(shoulder flexibility), leg power using (vertical and horizontal jumps), overhead throw (2kg medicine ball throw), speed tests (10, 20, and 40m sprint tests), agility (Illinois test) and aerobic fitness (Hoff test).

There were no statistically significant differences in age, body mass, height, fat mass, body mass index, lower back flexibility, right shoulder flexibility, 20m sprint, and endurance capacity (p>0.05). Statistically significant differences were found in percentage body fat (p>0.05), sum of 8 skinfolds, fat free mass, somatotype, left shoulder flexibility, upper and lower body power, 10m and 40m sprints (p<0.01). South African players were found to have higher %BF and sum of skinfolds and then Zimbabwean players.

It was concluded that Zimbabwean players performed significantly better than South Africans in agility, 10m, 40m sprints, vertical jump, horizontal jump and overhead throw and had better future chances of success in soccer. Goalkeepers were taller and heavier, while midfielders and defenders were found to be lighter and shorter. Goalkeepers were the most agile group, while forwards were the fastest group. Agility, power and speed were the most important variables that can be used during talent selection and coaches should purposefully work to develop these characteristic during training sessions. Height and weight are relevant in allocating positional roles to players and not in Talent Identification.

OPSOMMING

Talentidentifisering en vroeë seleksie in ŉ professionele sokkerakademie blyk baie belangrik te wees vir die langtermyn ontwikkeling van sokker vaardighede (Le Gall *et al*., 2010). Hierdie behoefte vir die vroeë identifisering van talentvolle jong spelers het aanleiding gegee tot ŉ toename in sokker sentra van uitnemendheid en akademies wêreldwyd. Tradisioneel is die identifisering en seleksie van belowende individue vir toelating tot ŉ jeug sokker akademie aan ŉ afrigter se subjektiwiteit en voorafopgestelde idees van die speler gekoppel. Wanneer die metode in isolasie gebruik word kan dit dodelike mistastings in talent identifisering teweeg bring – daarom die klem op wetenskaplik gebaseerde benaderings. Deur sokker spesifieke navorsing is daar alreeds ŉ aantal antropometriese en fisieke parameters aan suksesvolle prestasie in sokker gekoppel.

Die primêre doelwitte van die studie was om die antropometrie, somatotipe en funksionele fiksheidskenmerke van jong sokker akademie spelers in Suid-Afrika en Zimbabwe te ondersoek en om veranderlikes wat relevant vir talentidentifisering kan wees te onderskei. Die studie het ŉ kwantitatiewe, nie-intervensie ontwerp met ŉ gerieflikheidsteekproef gevolg. ŉ Totaal van 74 jong sokkerspelers van Suid-Afrika (n = 41) en Zimbabwe (n = 33) sokker akademies is doelgerig geselekteer (ouderdom 15.9 ± 0.81 jaar).

Die volgende antropometriese veranderlikes is ooreenkomstig met die *International Society of the Advancement of Kinanthropometry* (ISAK) protokol gemeet: liggaamsmassa en -lengte; velvoue (triseps, subskapulêr, biseps, iliokristale vou, supraspinalis, abdominale, quadriseps, mediale gastroknemius); omtrekke (arm ontspanne, arm in fleksie en gespanne, middel, gluteale, en kuit); been breedtes (biepikondelêre humerus en biepikondelêre femur). Funksionele fiksheidsveranderlikes wat gemeet is was: laerug spierlenigheid (sit en reik toets), boonste ekstremiteit lenigheid (skouer lenigheid), beenkrag (vertikale en horisontale

spronge), oorhoofse gooi (2kg medisyne balgooi), spoedtoets (10, 20, en 40m spoedtoetse), ratsheid (Illinois toets) en aërobiese fiksheid (Hoff toets).

Geen statisties betekenisvolle verskille is in ouderdom, liggaamsmassa, -lengte, vetmassa, liggaamsmassa indeks, laerug lenigheid, regterskouer lenigheid, 20 meter spoed en uithouvermoë kapasiteit ($p>0.05$) tussen SA en Zimbabwe spelers gevind nie. Statisties betekenisvolle verskille is wel in persentasie liggaamsvet ($p<0.05$), som van agt velvoue, vetvrye massa, somatotipe, linkerskouer lenigheid, boonste en onderste ekstremiteit liggaamskrag, 10m en 40m spoed ($p<0.01$) gevind. Suid-Afrikaanse spelers het 'n hoër persentasie liggaamvet en som van velvoue as die Zimbabwiese spelers gehad.

Daar is tot die gevolgtrekking gekom dat Zimbabwiese spelers betekenisvol beter as Suid-Afrikaanse spelers in die meeste fiksheidstoetse gevaar het en waarskynlik beter kanse vir sukses in sokker het. Doelwagters was groter en swaarder, terwyl middelveld spelers en verdedigers ligter en korter was. Doelwagters was die ratste groep, terwyl voorspelers die vinnigste groep was. Ratsheid, krag en spoed is as die belangrikste veranderlikes geïdentifiseer wat tydens talentidentifisering gebruik kan word en afrigters moet doelbewus daaraan werk om hierdie eienskappe tydens oefensessies te ontwikkel. Lengte en gewig is relevant in die toekenning van posisionele rolle aan spelers en nie in talentidentifisering nie.

Hierdie is die eerste studie waarin die antropometriese en funksionele fiksheidsprofiele van jong sokkerspelers in Suid-Afrika en Zimbabwe met mekaar vergelyk word. Dit baan die weg vir ander navorsers om hierop uit te brei deur sokkerspelers van ander lande in Afrika te toets en by te dra tot die kennis van sokkerspelers in Afrika. Hierdie navorsing skep ook die basis vir afrigters en oefenkundiges in Afrika om die bydrae wat die wetenskap maak ten opsigte van liggaamsamestelling en funksionele fiksheid beter te verstaan om talentidentifisering in sokker te verbeter.

ACKNOWLEDGEMENTS

At the end of every soap, it is the main actor who gets all the praises – as if he acted alone. I believe in '**No man is an island'**.

There are many people I would like to acknowledge for the role they played in the completion of this thesis. My sincere appreciation to my study leader Professor Terblanche for being my torch-bearer. Without your untiring guidance this destination could have been a dead-end. Your knowledge, dedication, determination and perseverance in the field of sport have opened a world of possibilities for me. I am forever indebted for your mentorship.

To my wife Fungai and kids, Tinotenda and Nokutenda, who have been treating me as a student more than a husband and father – you have been my pillars of strength through thick and thin. Your love and unwavering support cannot go unmentioned. This chapter has been closed - let us start a new one together. I am ever indebted to the Department of Sports Science at the National University of Science and Technology for provision of anthropometric equipment. My sincere appreciation goes to Mr D. Makaza for your guidance and assistance on statistical analysis.

To my friends Biggie, Benjamin, Privilege and Morris, the episode is too long to narrate - your support was quite warm; I appreciated every moment we spent together.

I LOVE YOU ALL.

-Thank you-

DEDICATION

I dedicate this piece of work to my family.

LIST OF ABBREVIATIONS

ADP	: air displacement plethysmography
ANOVA	: analysis of variance
BCM	: body cell mass
BF	: body fat
%BF	: percentage body fat
BIA	: bioelectrical impedance analysis
BM	: body mass
BMD	: bone mineral density
BMI	: body mass index
BV	: body volume
cm	: centimetre
CT	: computerised tomography
CODST	: change of direction speed test
COPD	: chronic obstructive pulmonary disease
Db	: body density
DEXA	: dual energy x-ray absorptiometry
DPA	: dual photon absorptiometry
ECW	: extracellular water
FFB	: fat free body
FM	: fat mass
FFM	: fat free mass
FMI	: fat mass index

FFMI	: fat free mass index
g/cc	: grams per cubic centimetre
HD	: hydrodensitometry
HW	: hydrostatic weighing
ISAK	: International Society for the Advancement of Kinanthropometry
IWC	: intercellular water
LBW	: lean body weight
MFBIA	: multi-frequency bioelectrical impedance analysis
MRI	: magnetic resonance imaging
NAA	: neutron activation analysis
ml/kg/min	: millilitres per kilogram body mass per minute
SANOVA	: somatotype analysis of variance
SAQ	: speed agility and quickness
SBIA	: segmental bioelectrical impedance analysis
SD	: standard deviation
SKF	: skinfold
TBBM	: total body bone mineral
TBK	: whole body count of potassium
TWD	: total body water
UWW	: underwater weighing

TABLE OF CONTENTS

Contents .... page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Physical and physiological performance variables of an athlete are frequently influenced by his/her body composition, morphology and fitness. Age, maturity and physical training also play a critical role in determining the body composition characteristics of athletes. The physical and physiological performance attributes of an individual improve with growth and maturity, however, there will always be differences between youths and adults, and sub-elite compared to elite athletes. Some sport, such as throwing events in track and field, wrestling, rowing and boxing demand participants to have high fat free mass, whereas in sport such as track athletics and gymnastics high body mass can undermine performance.

Therefore it is the quest of anthropometrists and researchers in kinanthropometry to establish the extent to which performance variations can be attributed to differences in quantitative and qualitative characteristics of the athletes. Thus analysis of body composition and functional fitness profiling can be a reliable way to determine the differences in body composition and fitness characteristics of homogeneous groups (Calleja *et al*., 2007; Underlay *et al*., 2005; Amusa, 2004; Kathmandu, 2001; Carter and Heath, 1990). This profiling is also the best method to determine a player's suitability for competition, particularly at elite level. Researchers in modern sport share the same notion that elite sporting performance is achieved once an athlete possesses some appropriate structural and functional characteristics fundamental to that particular sporting event (Singh *et al*., 2010; Gravina *et al*., 2008; Gil *et al*., 2007; Ostojic, 2003; Carter and Heath, 1990) and stressed the need to develop young soccer players' technical and physical capacities at a period before adolescence, as this is the decisive stage where appropriate training and motor skill acquisition determine the future progress of young players.

Body composition comprises of measures of percentage body fat (%BF), lean body weight (LBW), body mass index (BMI), stature, limb lengths and girths, as well as limb and body circumferences. Functional capacity includes measures of fitness characteristics such as agility, power, strength, flexibility, endurance and speed and how they determine the capacity of an individual to accomplish sport specific functions. Functional characteristics play a pivotal role in any sporting competition because they form the basis for successful performance. A specific magnitude of these variables is necessary to determine trainability of players, to monitor growth and development, as well as to predict possibility of future successful performance (Tumilty, 2000; Chin *et al.*, 1994; Reilly and Secher, 1990).

Ostojic (2002) indicated that a relationship exists between an athlete's body composition and functional fitness characteristics and pointed out that body composition and somatotype variables can greatly influence the attainment of functional characteristics such as strength, speed, power and flexibility by an athlete. These variables are thus used by exercise physiologists and coaches during talent scouting. They measure both anthropometric characteristics and functional fitness in an effort to determine factors that indicate future talent. This was substantiated by Le Gall *et al*. (2010) who studied players at France's elite soccer academy (Clairefontaine) and found that, youth players with significantly greater height, weight, jumping ability and maximal anaerobic power, were more likely to be selected for France's senior men national team game.

The technique of somatotyping is used to appraise body shape and composition. It is expressed in a three-number rating representing endomorphy, mesomorphy and ectomorphy components respectively, always in the same order. Endomorphy is the relative fatness, mesomorphy is the relative musculo-skeletal robustness, and ectomorphy is the relative linearity or slenderness of a physique (Carter and Heath, 1990). For example, a rating of 2-3-2 means two-endomorphy, three-mesomorphy, and two-ectomorphy. Each digit (2-3-2) represents the magnitude of each of the three components in this order. A rating of 0.5 to 2.5 is considered low, a rating 3 to 5 is moderate, between 5.5 and 7 is high, while a rating of 7.5 and above is extremely high (Carter and Heath, 1990).

Morphological features (body shape and size) are predominantly genotypic (genetically determined) and can be slightly altered through physical training, whereas body composition is more phenotypic (environmentally determined) and can be changed substantially through training and appropriate diet (Trembley *et al*., 2000; Hakkeinen *et al*., 1998). Thus an athlete may exhibit some physical features that specifically suit a specific sport and thereby separating him or her from athletes in other sport as well as from those in the non-athletic population. Functional characteristics are more phenotypic than genotypic and a player who possesses genetically acquired sporting skills must combine them with speed, strength, agility, power, and endurance before the inherent sporting skills can be utilized.

CHAPTER 2

BODY COMPOSITION AND SPORTS PERFORMANCE

A. Introduction

The human body consists of various components such as fat, muscle, bone, minerals, water and other elements. Muscle, bone, water and minerals form the fat free component of which water constitutes the highest percentage with 73.8%, minerals 6.8% and protein 19.4% (Heyward and Wagner, 2004). These elements contribute to the total body weight (TBW) and they form the basis of the quantitative description of a human in relation to its level of fatness and slenderness.

According to Heyward and Wagner (2004) the term body composition refers to the fat and fat free components of the human body. The proportions of each of the components have important implications for an individual's present and future health-related outcomes including cardiovascular, nutritional and psychological status as well as physical performance capability (Buskirk and Mendez, 1984). Fat is an essential component of the human body, as it is critical in maintaining normal physiological function and homeostasis. The majority of body fat is stored in adipose tissue in subcutaneous sites, although there is also some deposited around vital organs which play primarily a protective role (Nunez *et al*., 1999). However, excessive body fat is undesirable, given the strong associations to low athletic performance (Makaza *et al*., 2011; Singh *et al*., 2010; Malina *et al*., 2004).

B. Importance of body composition measurement

The appraisal of body composition gives vital information to a variety of professional fields which includes health, fitness and weight management, exercise and training as well as in schools and military service. In the field of exercise science and weight management, body composition assessments help both coaches and athletes to progressively monitor the effects of a training programme. Body composition measurements also play a significant role in the classification of athletes in sport with weight specific categories such as boxing, rowing, wrestling and gymnastics. In sports such as track athletics (100m, 200m, 400m, 800m, 1500m etc), field athletics (high jump, long jump, triple jump) and other sports which involve rapid weight transference and weight support over a distance, excess body fat can be a significant burden (Buskirk and Mendez, 1984; Ostojic, 2003b).

During prolonged training periods, it is possible that athletes may lose more weight than is desired or is considered normal. Therefore the assessment of body composition provides a criterion by which appropriate sport specific weight can be maintained (Fields and Goran, 2000). The effectiveness and reliability of a training programme can also be evaluated from the changes in body composition levels from time to time. Brownell (1992) propounds that changes in body composition are one of the common parameters used in evaluating the success of programmes.

Body composition assessment can also provide essential information on the nutritional status and dietary requirements of athletes. When exercise programmes are combined with a dieting programme, adiposity can be decreased, while lean body mass is maintained. Both these components can be objectively monitored with body composition analysis. In young children and adolescence, body composition appraisal provides diagnostic and prognostic data on malnutrition, as well as on wasting diseases such as osteoporosis and cardiovascular diseases which may obstruct their future potential to become professional athletes (Tremblay *et al*., 1990).

C. Body Composition Models

Body composition models are theoretical models, based on the chemical analysis of organs, whereby fat, total body water, mineral (bone and soft tissue) and protein content of the body are estimated (Withers *et al*., 1998). There are a number of models that can be employed in assessing human body composition.

1. The two component (2-C) model

The two component model was propounded by Behnke *et al*. in 1942. The model divides the human body into two components, namely fat mass (FM) and fat free mass (FFM). The two component model is one of the mostly used models in anthropometry (Jackson *et al*., 1988) and is based on the measurements of total body density (Db) using the hydrodensitometry method of body composition assessment.

2. The three component (3-C) model

This model was first developed by Siri (1961). It divides the human body into three components, namely fat, water and solids. The solids include protein and mineral fractions of the fat free body (FFB) combined. Densitometry and dual-energy X-ray absorptiometry (DEXA) are the common methods used to measure Db and estimate total body mineral content (Withers *et al*., 1998).

3. The four component (4-C) model

The four component model is used to estimate percentage body fat from Db in cases where hydration and relative mineral content of the body vary greatly, like in cases of severe malnutrition, illness or after prolonged training. The model divides the body into four fractions, namely fat, water, mineral and protein. The 4-C models have greater accuracy in estimating percentage body fat (%BF) compared to the 2-C models and the common methods used in this model are air displacement plethysmography (ADP) and bioelectrical impedance analysis (BIA) (Dewit *et al.*, 2000).

4. The six component (6-C) model (atomic model)

The six component model requires the direct analysis of the chemical composition of the body using the Neutron Activation Analysis (NAA). It divides the human body into six fractions, namely water, nitrogen, calcium, potassium, sodium and chloride. According to (Heyward and Wagner, 2004) the 6-C model is more accurate compared to all the other body composition assessment models, but it is expensive and it exposes the individual to radiation which may be harmful to his/her health. The methods that are commonly used in the 6-C model are: neutron activation analysis (NAA), computerised tomography (CT), magnetic resonance imaging (MRI) and whole body counting of potassium (TBK) methods. (Heyward and Wagner, 2004; Dewit *et al*, 2000)

D. Methods of body composition assessment

Body composition assessments can be done using both field and laboratory methods. Laboratory methods are more expensive, more inconvenient and more time consuming than field methods, however, they are more accurate than the field methods (Withers *et al.*, 1998).

1. Hydrodensitometry (HD)

Hydrodensitometry is also known as the hydrostatic weighing (HW) or underwater weighing (UWW) method. Densitometry refers to the measurement of body density. This method follows the principle of Archimedes, namely that ‘‘the volume of an object submerged in water is equal to the total volume of the water displaced by that object.’’ When an object is submerged in water, it is acted upon by a buoyant force of equal magnitude to the weight of the water it displaces. According to Heyward and Wagner (2004), hydrodensitometry is more precise in measuring body volume than other methods, especially when residual lung volume and that of the gastrointestinal (GI) tract are factored into the calculations of body volume and body density. This method is commonly used when assessing body composition using the 2-C model. They assert that the technical error of measurement of the HD method is very small (< 0.002 g/cc) and these errors typically emanate from the inaccurate or incorrect measurement of residual lung volume, body weight, water temperature, or the subject's ability to comply with testing procedures, the technician's skills in administering the tests, as well as the use of wrong conversion formulae which may overestimate the percentage body fat. The biggest source of measurement error when measuring Db using the HD method is failure to measure residual lung volume and GI volume (Wagner and Heyward, 2001; Withers *et al*., 1998).

2. Air Displacement Plethysmography (ADP)

ADP is another method used to measure body volume and body density. In this case an air displacement technique is used to estimate body volume rather than water displacement as in hydrodensitometry. The method is quick and demands minimal compliance by the client and minimum technical skills to administer the test (Withers *et al*., 1998). The modern ADP method uses the BodPod® fibreglass chamber which is egg shaped and relies on air displacement and pressure volume relationships to derive body volume (BV). The accuracy of BV measurements depends on the tester's ability to effectively monitor temperature changes and gas pressure that arise when the body is placed in the enclosed air displacement chamber. BV is determined from the changes in pressure inside the chamber, and is based on

Boyle's law which states that ''the volume and pressure of an object are inversely related (Heyward and Wagner, 2004).

The ADP BodPod® consists of two chambers. The subject sits in the front chamber during measurement, while the rear chamber is the reference chamber. In between the chambers is a moulded fibreglass seat which separates the chambers. A moving diaphragm is mounted on the fibreglass wall that oscillates during testing. The oscillation of the diaphragm creates minor changes in air volume which is of equal magnitude in both chambers, resulting in minor pressure fluctuations. The pressure-volume relationship is then used to calculate the volume in the front chamber. The procedure is done twice, firstly with an empty chamber and secondly with a client inside. The body volume is calculated as the difference between the chamber volumes when it is empty and when the subject is seated inside the chamber (Fields and Goran, 2000).

It is reported that the ADP BodPod® has comparable accuracy to the hydrodensitometry method. No significant differences ($p<1.2$) were reported between BF estimates from the ADP BodPod® and HD in children (Demerath *et al*., 2002; Dewit *et al*., 2000; Wells *et al*., 2000; Nunez *et al*., 1999). Comparing the BodPod® to DEXA, some researchers reported that the BodPod® underestimates the average %BF by 1.9-2.2% in children and by up to 2.8% in adults older than 60 years (Fields and Goran, 2000; Lockner *et al*., 2000; Nicholson *et al*., 2001).

3. Dual-Energy X-ray Absorptiometry (DEXA)

In the early 1980's, anthropometrists used the Dual-Photon Absorptiometry (DPA) to assess total body bone mineral content (TBBM) and bone mineral density (BMD) (Gotfredsen *et al*., 1984; Mazess *et al*., 1984; Peppler and Mazess, 1981). The DPA method uses the attenuation of photon beams from a radionuclide source to identify body tissue. In the 1990s, the DPA was replaced by the DEXA method which uses X-ray tubes rather than radioactive isotopes. It can be used to assess regional/segmental body composition and can provide separate estimates of total lean mass excluding bone mass, FM, FFM and %BF. It offers more accurate measurements of bone mineral density (BMD) and total body bone mineral (TBBM) of 1-3% compared to other multi-component models (Mazess *et al*., 1990). The efficiency of DEXA varies between different manufacturers, models and software versions, as there is no specific standard to be followed by manufacturers (Modlesky *et al*., 1996; Tataranni *et al*., 1996). The DEXA method is not recommended for use in clients whose body dimensions exceed the length or width of the scanning bed (Roubenoff *et al*., 1993; Lohman, 1992).

4. Magnetic Resonance Imaging (MRI)

The MRI method works by creating a computer-generated image of the human body from radio frequency signals emitted by hydrogen nuclei which act like small magnets (Heyward and Wagner, 2004). An external magnetic field and a pulsed radio frequency are applied across the client's body which will cause the nuclei to line up and absorb energy. When the radio frequency ceases, the radio signal is emitted from the nuclei. The emission is then used to create the image. The MRI method is best suited for measuring body composition at tissue level, as it can separate total adipose tissue from its subcutaneous and visceral components (Heyward and Wagner, 2004). According to Tinsley *et al*. (2012) fat, muscle and body water display different characteristics in response to radio frequencies of different magnitude at certain static magnetic fields thereby making them easy to distinguish. However, there is limited data available on the validity and reliability of MRI in clinical settings. In a study to evaluate the precision and accuracy of the MRI method using mice Tinsley *et al*. (2012) found that the precision of MRI was better compared to DXA. They reported a coefficient of variation for fat ranging from 0.34-0.71% for MRI against 3.06-12.6% for DXA. They concluded that MRI provides a fast, precise, accurate and easy-to-use method for determining %BF and lean body tissue.

5. Computerised tomography (CT)

Computerised tomography is a radiological method that measures the weakening of X-ray beams as they pass through the client's body. The attenuation differences are related to the differences in the densities of the underlying tissues (Fields and Goran, 2000). A computer generated image formed from the X-ray beams allows the recognition of bone, fat tissue, and fat free tissue separately. However, the method is not recommended when assessing the whole body due to exposure to radiation which can be harmful to the client. Therefore it should only be used when assessing regional body composition (Heyward and Wagner, 2004). Due to its limited use in laboratories, no statistics are available on this method on its reliability and validity compared to other methods.

6. Neutron Activation Analysis (NAA)

The NAA method measures human body composition at atomic level, whereas most of the previous methods measure body composition at cellular level. A beam of neutron is passed through the subject's body which forms isotopes and emits gamma rays. The quantity of each element is then determined by measuring its emissions. The 6-C body composition model uses NAA technology as a criterion method for evaluating other reference methods (Wither *et al*., 1998). NAA can be used to determine the total body content (oxygen, carbon, calcium, sodium, chloride, hydrogen, nitrogen and phosphorous) and is the most sophisticated method of body composition assessment (Fields and Goran, 2000). The use of NAA is limited by the cost of the equipment and facilities, as well as lack of expertise in this technology (Heyward and Wegner, 2004).

7. Bioelectrical Impedance Analysis (BIA)

The BIA technique was pioneered by Thomasetts in the year 1962 as a rapid and non-invasive technique to assess body composition in both clinical and fields settings. BIA involves the application of a low level electrical current through the subject's body. The resistance to the current (called impedance) is measured using a BIA analyzer. More resistance to the flow of the current is measured in fat tissue because of its poor conductivity due to its low water content (Jackson *et al*., 1988). On the other hand, if total body water (TBW) is high, there is less resistance to current flow given that electrolytes in the body water are good conductors of electrical current. Individuals with a large FFM and TBW therefore have less resistance to electrical current flow through their bodies compared to those individuals with a smaller FFM (Wither *et al*., 1998). Gray *et al*. (1989) observed a significant relationship between impedance measures and TBW ($r > 0.97$) and reported that the BIA technique could be the best method to analyse body composition in a clinical setting. BIA method can be used to estimate body composition of obese subjects and does not invade the subject's privacy (Jackson *et al*., 1988). Schols *et al*. (1991) reported a correlation of $r=0.93$ between impedance and TBW in patients with chronic obstructive pulmonary disease and suggest that BIA is the best method to measure body composition in COPD patients.

There are many BIA models that are used in anthropometry namely; BIA traditional model, parallel model, segmental model as well as multi-frequency model. The traditional BIA (electrophysical) model involves a whole-body (wrist-to-ankle) measurement of impedance at a single frequency of 50 kHz to estimate TWB and FFM. The traditional method is reported to be the preferred method compared to other methods when measuring normal healthy

clients (Kyle and Pichard, 2000; Gudivaka *et al*., 1999; Thomas *et al*., 1998). The parallel model uses a resistor and a capacitor wired in parallel. According to Ellis *et al*. (2000), the parallel model is commonly used to estimate intercellular water (IWC), body cell mass (BCM) and changes in IWC and BCM. The model is most preferred for measuring malnourished patients as well as those with fluid imbalances (Gudivaka *et al*., 1999).
The segmental model (SBIA) involves the separate measurement of each body segment (lower limb, trunk and upper limb) and is important for measuring patients with altered and abnormal fluid distribution, e.g. those undergoing haemodialysis. The SBIA model is reported to be less helpful when measuring healthy clients (Thomas *et al*., 1998).

The multi-frequency model (MFBIA), also called bioelectrical impedance spectroscopy (BIS), measures a wide range of frequencies and provides separate measures of ECW, ICW and TBW. Since the single frequency BIA device is limited to only 50 kHz, it only measures the ECW at this frequency. Therefore it excludes ICW which requires high frequency to penetrate the inner cell in order to measure the intercellular water. According to Thomas *et al*. (1998), the MFBIA method generates many data points making it difficult to understand and interpret. This method is best used in certain research settings, but not for everyday client monitoring.

The BIA method uses generalized equations and population specific equations to predict the %BF of the client by calculating fat mass (FM=BW-FFM) and then dividing FM by body weight.

%BF=FM/BW x 100.

Similar %BF results were reported for BIA and SKF in collegiate wrestlers (Utter *et al*., 2001), BIA and DEXA in children (Sung *et al*., 2001) and BIA to the hydrodensitometry method (Williams, 2000) reported reliability for multiple resistance measurements of 1-2%

for same day measurements and between 2-3.5% for different day measurements. Tinsley *et al*. (2012) reported similar reliability (r > 0.97) for same-day measurements, different-days and inter-machine reliability of resistance measurements for BIA. In a study to determine the reliability and validity of the BIA method compared to SKF and hydrostatically measured percentage fat, Jackson *et al*. (1988) measured 44 women and 24 men and retested them 4 times using 2 testers on 2 different days. They found that all three methods were reliable (r = 0.96-0.99) with standard errors ranging from 0.9-1.5 in % fat.

The validity and accuracy of BIA methods relies on the effective monitoring of factors that may increase the measurement error (Gonzalez *et al*., 2002; Gonzalez *et al*., 1999), which include knowledge of the specific equations programmed in the BIA machine, taking measurements from the right side of the body while the patient lies supine, cleaning of the skin with alcohol pads and proper placement of sensor electrodes. Accuracy also depends on the client's ability to strictly observe the BIA testing guidelines designed to control their hydration status. For example eating and drinking is not recommended in the 4 hour period prior to testing. Vigorous exercises are not allowed within 12 hours of the test. Clients should empty their bladders within 30 minutes of the test. Alcohol and diuretics should be avoided for seven days before the testing and no testing should be done on women during their menstrual cycle (Heyward and Wegner, 2004).

8. Skinfold (SKF) Method

Skinfolds are an indirect method of measuring the thickness of subcutaneous adipose tissue. Skinfold thickness correlates with %BF and this relationship is used to estimate body fat percentage (Heath and Carter, 1990). Subcutaneous tissue contains varying amounts of fat in various regions of the body, therefore the technique involves measuring the thickness of two layers of skin and underlying subcutaneous fat at selected sites using a skinfold calliper. The measures are used to estimate total body density and from this %BF is calculated.

The skinfold technique is inexpensive and easy to use and is most preferred for large scale epidemiological surveys to check the health and nutritional status of children and adults, as well as in monitoring the levels of subcutaneous fat deposits for subjects during training and weight management programmes (Kuczmarki *et al*., 1994). According to Ayvaz and Cimen (2011) when body fat is measured from skinfolds there is a margin of error of between 3-11% fat. Jackson and Pollock (1988) reported a percentage margin of error of 3-9% and attributed the measurement error to differences in techniques between SKF technicians.

Research has shown that skinfold measurement compare well with magnetic resonance imaging (MRI) and DEXA. Gutin *et al*. (1996) compared the body composition of 43 children (9-11 years old) using SKF, MRI, DEXA and BIA methods. They found that the %BF values of these methods were strongly correlated ($r > 0.83$), however, the mean score for DEXA was higher (23.98) compared to that for SKF (21.05) and BIA 21.52. There was no significant difference in %BF estimates between the 4 methods ($p < 0.01$). Orphanidou *et al*., 1994) reported a reliability range of between 0.96-0.96 when comparing SKF to the DEXA method.

Similar to BIA, prediction equations are used to predict Db from skinfold measurements, circumferences and girths. These prediction equations can be either population specific or generalised equations (Jackson and Pollock, 1986). Generalized equations are more preferred than population specific equations in that only one equation can be used to calculate BF for different clients, whereas the application of population specific equations are more limited (Heyward and Wagner, 2004). Gatin *et al*. (1996) highlighted various advantages for using the SKF technique compared to other body composition techniques and say the equipment is inexpensive and portable and can thus be used both indoors and on the field. The equipment is easy to use and does not require intensive training on the part of the measurer. However, the technique is time consuming and measurement errors may arise when the measurer is not consistent, especially on land marking the skinfold site. According to Fields and Goran (2000) errors may also arise if specific pre-measurement guidelines are not followed, e.g. avoiding eating or liquid consumption and physical exercises before testing. Thus there is need for adequate knowledge of principles and general guidelines for using skinfold technique to achieve accuracy.

The skinfold technique can be applied both to children and adult subjects as there are age-specific equations. However, they also noted some demerit for the skinfold thickness technique and say that this technique cannot distinguish individual variation in fat distribution patterns (i.e. one cannot determine the %BF for various specific regions or segments of the body). Jackson and Pollock (1988) warned about the dangers of using adult equations on children or vice-visa and say it can result in overestimating the %BF for children or underestimating that of adults. They also noted that the equations for children have not been sufficiently cross validated for specific sub-populations such as athletes and individuals of different racial and ethnic background.

E. Body composition and physical performance

Body composition has been known to influence success in sport performance (Maud and Cortez-Cooper (1995). Similarly demands for certain sporting events can also determine the body composition an athlete should possess – a process known as 'morphological optimization' (Bloomfield *et al.*, 1995). In events such as discus, shot put, hammer throw, wrestling, rowing and boxing, high levels of fat free mass are a determinant of success. In track athletics, gymnastics, jumps as well as other sports which require carrying weight over a distance, leanness influences the possibility of success (Singh *et al*., 2010). Carter (1984) reported that athletes who possess sport-specific body shapes have better chances of being successful in the sport once they receive appropriate training. Thus sport specific training has an influence in determining success in a sport. Toriola *et al*. (1985) also stressed that body size, shape and proportion of athletes are important considerations in sport performance.

According to Sinning (1996), body composition measures are widely used to prescribe desirable body weights, optimize competitive performance and assess the effects of training. Most studies in kinanthropometry have generally agreed that a minimum relative body fat is desirable for successful sporting performance (Abraham, 2010; Singh *et al*., 2010; Carter and Heath, 1990). Excess body fat adds more weight to the athlete's body with no contribution to energy. Sinning (1996) also stresses the fact that a high quantity of fat mass is disadvantageous in sports where the body is moved against gravity such as in high jump, basketball (shooting), pole vaulting and gymnastics. Abraham (2010) points out that the oxygen requirement of an athlete is directly related to his/her body weight when running at a sub maximal speed. Thus the demand for oxygen increases when the body weight is high. Large bodies also require more energy to initiate and sustain movement.

Researchers have shown that athletes in running and jumping sports are generally ectomorphic compared to those in team sports who are more likely mesomorphic. Abraham (2010) analysed the body composition and performance variables of 19 year old Indian athletes. The group comprised 93 track and field athletes (sprinters, middle and long distance runners), jumpers (high, long and triple jumpers) and throwers (shot, discus and hammer throwers). He observed that throwers were the heaviest among the group and long distance runners had the lowest body mass. The Body mass index (BMI) for all three groups was found to be within the normal (non-obese) range. However, throwers had the highest BMI values of all the other athletes. They also had significantly higher skinfold values (for all skinfold sites measured), reflecting a higher subcutaneous adiposity. There were no differences in skinfold value among sprinters, middle and long distance runners. Jumpers had the lowest skinfold values. Sprinters had the lowest fat mass and %BF, while throwers showed the highest values of fat mass and %BF. Thorland *et al*. (1983) determined the body composition and somatotype characteristics of junior Olympic athletes (men and women) and observed similar results as those of Abraham (2010). Athletes in the throwing events were heavier, taller and fatter compared to all other athletes in different sporting disciplines.

Singh *et al*. (2010) analysed the body composition and anthropometric variables of Indian high jumpers (using the DEXA method) in relation to jumping performance. The aim of the study was to establish the differences in performance between high and low performer jumpers between the ages of 18-25 years. They observed that high performers had higher levels of total body weight (TBM), due to higher lean body mass values than low performers, while low performers had significantly higher %BF than high performer jumpers. This indicates a better training status of high performers compared to low performer jumpers, and also that higher %BF can be detrimental to sporting performance. Higher levels of lean tissue mean more muscle tissue which will contribute to strength and power, speed, speed endurance and aerobic capacity (Bloomfield *et al*., 1995). Thus the optimal body composition for an athlete is the one which is composed of high proportion of FFM and small proportion of FM (Singh *et al*., 2010).

F. Body composition changes at adolescence

1. Changes in height and weight

The pattern of body composition changes is similar for all children, however, body size attained at certain age and the timing of the adolescence growth spurt vary from child to child

(Malina *et al*., 2004). From the time of birth up to early adulthood, weight and height assume a certain sequence, i.e. accelerated growth at infancy and early childhood; steady growth at middle childhood; accelerated growth during adolescence and a slow increase till growth stops at adulthood height (Malina *et al*., 2004). According to Bouchard *et al*. (1997) growth in sitting height and leg length determine the total stature. Gender variations in these two variables are negligible during childhood. At early adolescence leg length for girls is slightly longer compared to that of boys but only for a short time, while sitting height for girls remain higher for a longer period. Boys surpass girls in leg length at around the age of 12 years but they do not catch up with girls on sitting height until approximately 14 years (Malina *et al*., 2004; Bouchard *et al*., 1997). The early adolescents' growth spurt is characterized by rapid growth of the lower extremities thus increasing leg length more than sitting height, a factor assumed to result in poor flexibility scores in adolescent boys (Wells *et al*., 2000; Bouchard *et al*., 1997). Growth in leg length ends earlier than sitting height and sitting height continues to increase into late adolescence up to about 20-22 years (Malina *et al*., 2004). Thus sitting height contributes more to adolescents' growth spurt in height.

2. Changes in Fat Free Mass (FFM)

Changes in the FFM component (water, mineral, and protein) due to growth and maturation influence the density of FFM in children (Roemmich *et al*., 1997; Boileau *et al*., 1985). Major changes in body composition take place with growth from childhood to adulthood until a stage when the concentration of water, protein and minerals become constant in the fat free cell (a stage known as chemical maturation) i.e. at approximately the age of 22 years (Malina *et al*., 2004). During infancy water contribute greatly to total body weight. As growth progresses to adolescence and adulthood, the contribution of water to TBW declines resulting in a decrease in total body weight. Malina *et al*. (2004) estimated that the total body water decreases significantly from 75.1-62.4%, protein increases from 11.4-16.4%, minerals from 2.5-5.9%, and fat from 11.0-15.3%. Thus the contribution of protein, mineral and fat to total FFM increases and that of water decreases at adolescence.

FFM is high in childhood due to a high content of total body water and decreases as one progresses to adulthood as the hydration levels of the body decreases. Protein, fat and minerals increase with increase in age for males and this result in an overall increase in FFB density (Wells *et al*., 2000; Roemmich *et al*., 1997). From birth to about the age of 22, FFB density increases steadily in males from 1.096 g/cc (Roemmich *et al*., 1997) Lohman (1992) calculated the FFB density of pre-pubertal and pubertal children (8-14 years) from Europe and noted that FFB density of pre-pubertal boys was 1.084 g/cc and 1.086 /cc for girls and was significantly lower compared to that of pubertal children (1.087 g/cc for boys and 1.091 g/cc for girls). Nunez, *et al*. (1999) reported a mean fat free body density for 8-12 year old boys and girls of 1.0864±0.0074 g/cc and there was no significant difference between genders. They reported a decreased water component of FFM from 79% from birth to 74% at early adolescence (12 year) and an increase in bone mineral component from 3.7 to 7.0%. Gender differences in relative body composition of FFM are insignificant at infancy and become visible in early childhood.

3. Changes in fat mass (FM) and percentage body fat (%BF)

Total body fat increases during the first 2-3 years from birth and slightly changes up to 5-6 years. Gender variations are negligible at this stage. FM increases more rapidly in girls than in boys through adolescence, and reaches a plateau at adolescence growth spurt in boys (13-15 years). Total percentage body fat increases rapidly in both genders at infancy and then decreases gradually from early childhood. From age 5-6 years to adolescence, girls tend to have greater %BF compared to boys (Bouchard *et al*., 1997). In boys %BF increases gradually until around 11-12 years (before growth spurt) and steadily decreases to reach its lowest at adolescence (16-17years), after which it rises at early adulthood. Malina *et al*. (2004) tracked European athletes and non-athletes to compare the relative fatness from late childhood to adolescence. They reported a decline in relative fatness but athletes had lower relative fatness at all ages. They noted a wider difference between boys and girls as the subjects approached adolescence age.

4. Changes due to the genetic influence

Body composition is reportedly influenced by heredity, i.e. the effect of parental generation on the offspring which is caused by a gene or a set of genes encoded in the DNA of the cells (Malina *et al*., 2004; Bouchard *et al*., 1997). It can also be influenced by cultural and inheritance factors linked to ethnicity, race practises, i.e. shared environment and social conditions or lifestyle characteristics transferred from parents to children through education, modelling or economic status. At infancy, the genetic influence on height and weight is negligibly low and only becomes apparent during of the growth spurt and adulthood (Bouchard *et al*., 1997).

According to Malina *et al*. (2004) the genetic influence of height is higher compared to the genetic influence of body weight and that for height it tends to be greater in well-nourished groups and in whites, compared to under-nourished and other ethnic groups. Genetic contribution to height at any given age (childhood, adolescence and adulthood) is estimated to be around 60%. This means that at least 60% of individual differences in height of an individual are due to genetics, while the other 40% is due to phenotypic characteristics. Malina *et al*. (2004) postulates that certain environmental factors (nutrition, lifestyle and economic status) may have strong influence on growth and maturation for some children, but less on other children thus making it difficult to determine by how much each factor (genetic or environment) contributes to growth and maturation.

Research has revealed that genetic variation also play a role in modulating metabolic characteristics of adiposities and contribute approximately 25-40% of variations in %BF (Malina *et al*., 2004; Roemmich *et al*., 1997). The other 60-75% is due to environmental factors such as nutrition, culture and lifestyle, such as the physical activity habits of an individual. The distribution of subcutaneous fat is also thought to be influenced by genetic factors, thus some families tend to accumulate upper body fat while others accumulate it in the pelvis region (Roemmich *et al*., 1997).

G. Influence of training on body composition and performance

Forbes (1987) and Malina (1996) asserted that differences in body composition among athletes (especially those from different countries of origin) can be due to differences in ethnicity, lifestyle factors (diet, activity level and training status), as well as climatic factors. O' Hara *et al*. (1979) studied changes in fat content of fifteen middle aged, moderately obese male soldiers involved in a 2 weeks arctic patrol. They observed that exposure to cold conditions led to the reduction of skinfold thickness, increased Db, decreased BF content and increased lean body mass. However, the temperature before the cold exposure was not measured or noted.

Legaz and Serrano (2005) performed a longitudinal study to determine if changes in skinfold thickness induced by training and conditioning over a 3 year span in 37 high level men and women athletes were related to changes in running performance. Measurements were taken at the beginning of each year, during the competitive season and at the end of each year. They reported a slight decrease in the sum of skinfolds and slightly improved running performance over the three year period, but no changes in body weight. They reported that loss of BF was specific to muscle groups used during training and most particularly those in the lower extremities. The lack of change in body weight was due to a gain in lean tissue to compensate for the loss in BF.

Koutedakis (1995) reviewed a number of studies which focused on seasonal variations in body composition and fitness parameters in competitive athletes and noted that 50% of the these studies reported no change in subcutaneous fat during the competitive season in various sports due to the fact that athletes would have reached the appropriate level of BF and would not further lose any BF when training, as well as due to already low baseline BF at the beginning of the season Koutedakis (1995) suggested that a significant change in BF levels is more pronounced when athletes' initial/baseline fitness levels are low. He further asserts that greater differences in body composition are observed in cross sectional studies and in athletes of low training status. However, Ostojic (2003) examined the effects of training on body composition and performance in professional Yugoslavian soccer players. Skinfold measurement was done at the beginning of pre-season conditioning, during the competitive season and end of season. He found that body mass dropped significantly at the end of season compared to pre-season from 77.8±6.3 to 74.8±6.0 kg, while %BF dropped significantly compared to the early and mid-season levels from 11.5±2.1-9.6±2.5%. He attributed this finding to the effect of training and competition demands of the game. No significant differences were observed in fat free mass, from 68.8±5.3- 67.6±5.3%. He concluded that body fat of professional players change significantly during the early season conditioning and competitive periods because players would have accumulated more fat during off season.

H. Anthropometric requirements for successful performance in soccer

According to Reilly *et al*. (2000a) there are no globally agreed anthropometric variables that are important to predicting long term success in soccer. Borms (1996) reported that anthropometric variables (height, weight) and body composition (%BF and somatotype) are correlated to successful performance in sport but their effectiveness in soccer has not been universally agreed upon or quantified. Chamari (2011) stated that body composition is a key factor in soccer, as it can be used to determine the preparedness of young players to accommodate training loads, to assess their trainability, as well as to monitor the effectiveness of a training programme.

Many studies have tried to establish certain anthropometric requirements for playing at elite level in soccer. Reilly *et al*. (2000) singled out sum of skinfolds, percentage body fat and endomorphic component of somatotype. Gil *et al*. (2007) specified height, weight, age and maturity level and (Williams, 2009) regarded appropriate height and weight, age and maturity as well as sum of skinfolds as important. However, the optimum values for each variable that soccer players should possess were not quantified.

The mean weight and height for youth soccer players (14-19 years) as reported by various authors range from 49.9±0.4 - 71.3±6.8 kg and 163.9±0.3 - 178.6±6.3 cm, respectively and for adult players range from 72.1±8.0 – 78.4±7.4kg and 177.2±4.5 – 190±6.0 (Pittoli *et al*., 2010; Stolen *et al*., 2005; Chamari *et al.*, 2004; Rahkila and Luthanen, 1989; Leatt, *et al*., 1987). According to Malina *et al*. (2004), the weight and height of a soccer player are important contributors to functional test performance such as speed, vertical jump, and to soccer specific skill performance such as heading, shooting, passing and goalkeeping.

Gil *et al*. (2007) performed a cross-sectional study on the anthropometric and physiological characteristics of 241 young soccer players from Getxo Academy in Spain (14-17 years). The aim of the study was to explore how these characteristics can be useful for selection process. They compared players who were selected into higher level teams to those who were not selected. All players were given the same training during their period in camp; therefore any differences in observed variables were not due to differences in training programs or training status of athletes. They found that players who were selected to play for the next age group were taller and heavier than the non-selected players. However, while this could suggest the importance of body size in soccer, they noted that 66% of successful players were born in the first semester of the year, which could be a major contributing factor to higher values of height and weight of selected players. Thus the relative-age-effect can be an important factor in talent selection and not body size per se.

In their studies on anthropometric characteristics of elite versus sub-elite and professionals versus non-professional, starters versus substitute young soccer players, Ostojic (2003), Reilly *et al*., (2000) and Bangsbo (1994) found that taller and heavier players feature as goalkeepers and central defenders, while shorter and lighter players play as midfielders and forwards. Thus body size, height and weight are of advantage in soccer depending on the positional role of players (forwards, midfielder, defenders, goalkeeper), as well as in match-play situations. Reilly (2000) noted that height helps to attain maximum jump to reach high balls especially when defending, while large body mass plays a role in adding momentum in ball-shooting as well as assisting to avoid being tackled by opponents. This further substantiates the point that body size (weight and height) is important in soccer but it cannot be used as a discriminating factor when selecting future talent in young soccer players.

Percentage body fat and somatotype were reported to be critical in determining sport performance (Gil *et al*., 2010). However there are no established %BF and somatotype requirements that are prescribed for soccer players or that can distinguish successful from non-successful soccer players. Bloomfield *et al*. (1995) stipulates that %BF of between 7-

19% is desirable for young and adult soccer players and a somatotype value which is high in mesormophic components is required.

The mean percentage body fat for young players reported by various authors range from 7.2±3.0-16.1±4.3% (Makaza *et al*., 2012; Salgado *et al*., 2008; Gil *et al*., 2007; Tabara *et al*., 2006; Valtuefia *et al*., 2006). Salgado *et al*. (2008) reported somatotypes for Portuguese young soccer players as 3.03-4.78-2.55, which is a balanced mesomorph. Gil *et al*. (2007) and Makaza *et al*. (2012) reported somatotypes of 2.1-4.3-2.8±0.5-0.9-1.0 and 1.4-4.4-3.2 for young Spaniards and Zimbabweans, respectively. Reilly *et al*. (2000) reported a somatotype for Copa America elite senior soccer players as 2.0-5.3-2.2, and that of young elite players as 2.1-4.0-2.9±0.5-0.9-0.9 and state that somatotype for both young and adult elite soccer players follow similar patterns, of having higher value for the mesomorphic component and lower endomorph. The findings are similar to those of Bloomfield *et al*. (1995) who asserted that elite soccer players are mesomorphic-ectomorphs, i.e. they are muscular, which is an indication of a higher component of fat free mass.

I. Influence of maturation and relative age on soccer performance

Maturity is a 'state' whereas maturation is a 'process'. According to Malina *et al*. (2004), maturity is the extent to which an individual has progressed to the mature state or adulthood and maturation refers to the progress towards maturity. Maturity status is calculated as the difference between skeletal age and chronological age (Malina *et al*., 2004; Mirwald *et al*., 2002). Researchers in soccer and other team sport categorise maturity of players as late (delayed), average (on time) or early maturers (Mirwald *et al*., 2002). A positive score means that skeletal age is in advance of chronological age and a negative value indicates that skeletal age is lagging behind chronological age (Mirwald *et al*., 2002; Malina *et al*, 2000). Early maturity is when skeletal age is ahead of chronological age by at least more than one year. Late maturity is when skeletal age is behind chronological age by at least one year. Average or on time status is when chronological and skeletal ages are equal or differ by less than a year (Mirwald *et al*., 2002; Malina and Bouchard, 1991).

Youth soccer competitions are structured according to age groups which span 1-2 year periods, for example under 16 age group includes the players who are 14 and 15.9 years. The major aim of this age group classification is to ensure that children's sport development is in age-related stages, to reduce the risk of injuries, to promote fair competition and to ensure equal chances of success for everyone (Malina *et al*., 2000). The Federation of International Football Association (FIFA) considers the year of birth as the selection criterion that should be used by its Member States for all youth sport and defines the cut- off date for age categorisation as January 1 each year. This means that players within the same age category can have a difference in chronological age of close to 12 months. That difference in age among players within one age group is referred to as relative age and the effect of the age differences is known as the relative age effect. According to (2009) a difference of a year in growth and development can result in major differences in soccer performance among players of the same age band.

Maturity status and relative age are reported to have an influence in the physical and functional performance of youth soccer players (Pittoli, 2010; Le Gall *et al*., 2007; Malina, 2005; Malina *et al*., 2004). Early maturers tend to have a physical performance and skill proficiency advantage over late maturers which culminates in older player being preferred in talent identification over later maturers (Williams, 2009; Werner and Helsen, 2007; Malina *et al*., 2004; Malina, 2000).

In a study to determine the relationship between maturity and functional performance among under 17 Spanish youth soccer players, Rovina *et al*. (1991) observed that chronological age contributed more to the variation in performance in 60m sprint and 500m run compared to other variables such as body size, skill and experience. 72% of the differences in 60m sprint and 75% of the differences in 500m run were due to the influence of maturity; the remainder was a contribution of other factors such as body size (height and weight), experience and skills. Baxter-Jones (1993) reported a higher aerobic capacity in English elite junior players who were born in the first semester of the year compared to those who were born later in the year.

In soccer it has been reported that early maturity players are commonly favoured for team selection compared to the delayed maturity players because they will be advanced in trainability and skill performance as a result of advanced age (Malina, 2000). Honert (2012) analysed the birth dates for major junior leagues and National league players in Canada and observed that players' dates of birth decreased in frequency as you move towards the year end. Meaning to say most of the players in these teams were born in the early months of the year. It was concluded that the relative age effect among these teams was brought by the selection criterion of grouping junior into single-year cohorts for entry into organised soccer. It was further asserted that height, weight, speed, coordination, aerobic and anaerobic capacity and trainability of players are highly correlated with age, hence older players within an age band on average exhibit superior performance compared to their younger counterparts. However Le-Gal *et al*. (2009) argues that relative age effect and maturity status can work as talent identification variables when coaches use competition as the talent identification model to select potential players. Due to advanced age, older players will have an edge during competition over younger players. If other talent identification criteria other than competition were to be used, both early and late maturity players are likely to stand equal chances for selection.

J. Summary

The literature highlighted the various body composition assessment methods that can be applied both clinically and on the field. It was noted that these methods have their advantages and disadvantages that make them preferred or not preferred for use over the other. Changes in body composition occur from childhood to adulthood which range from visible changes in weight and height and those that cannot be seen by the naked eye. These include changes in percentage body fat, changes in fat free mass, changes in bone mineral content which can only be determined through measurement. These changes in body composition can be influenced by the maturation process, genetic make-up of the individual or can be induced by environmental factors such as lifestyle, climate, physical training, culture etc. and can be advantageous or disadvantageous in different sports. Researchers agree that body composition measurements are important in soccer but there are no specific standards that have been agreed as appropriate for soccer player that can induce performance improvement.

CHAPTER 3

PHYSICAL AND FUNCTIONAL FITNESS IN SOCCER

A. Introduction

For athletes to cope with the physiological demands of soccer, they should be competent in various fitness components: strength, aerobic and anaerobic capacities, flexibility, speed, agility, power and coordination (Malina *et al.*, 2004). These fitness attributes enhance the acquisition of technical and tactical skills of a player (Ostojic, 2002) and are crucial in evaluating functional performance variations of players in individual and team sport. (Hoff, 2005). Therefore coaches and players should devote a considerable amount of their training time towards development of these fitness components in order to maximize their playing potential.

B. Physical fitness

Pate (2012) defined physical fitness, as a state characterized by (a) an ability to perform daily activities with vigour, and (b) demonstration of traits and capacities that are associated with low risk of premature development of the hypokinetic diseases (i.e., those associated with physical inactivity). *"Physical fitness is the ability to carry out every day duties energetically with caution and alertness, without undue fatigue and remain with sufficient energy to engage in leisure-time pursuits* (Corbin *et al.*, 2000) *and to meet other physical stresses encountered in emergency situations"* (Rikli and Jones, 2001). Malina *et al*. (2004a) describe physical fitness as "*a state or a condition that allows an individual to carry out daily activities without tiring quickly and spare some energy to enjoy active leisure."* Pate and

Shephard, (1989) say that physical fitness includes having appropriate cardiorespiratory endurance, body composition, muscular strength and flexibility.

C. Functional fitness and soccer

Pate and Shephard (1989) describe functional fitness as having adequate levels of the following physical fitness variables; strength, power, speed, agility, balance, flexibility and coordination which enable one to complete a functional task efficiently. Svensson and Drust (2005) describe functional fitness capacity as the integrated effort of the pulmonary, cardiovascular and skeletal muscles system which determines one's functionality and is synonymous to exercise tolerance. According to Rikli and Jones (2001) functional fitness is having sufficient strength, flexibility, mobility and endurance to perform everyday activities safely without getting fatigued. This shows that physical and functional fitness are inseparable, in fact, Singh *et al*. (2010) stated that functional capacity depends on physical fitness. According to Reiman and Manske (2009) functional capacity cannot be quantified in an appropriate manner hence it is difficult to measure directly. Thus, functional capacity is mostly estimated from the physical fitness variables (flexibility, agility, strength, speed, coordination, power, and balance). This therefore means that for players to functionally perform technical and tactical skills required in a particular sport, they should possess a high degree of physical fitness. Therefore, with specific reference to sport, functional capacity is having that fitness which is directly related to performance in the specific sport.

In soccer, functional fitness capacity can therefore be described as the capacity of a soccer player to possess the specific level of fitness that can help him/her to efficiently accomplish the demands of a soccer match such as dribbling, passing, turning, shooting, sprinting and changing direction. According to Ostojic (2002) functional training in soccer should have an emphasis on physical, technical and tactical demands of the game as well as the demands of a specific playing position. Reilly *et al*. (2000a) stated that the positional role of a player is related to his or her functional capacity. Thus, training should be aimed at developing specific functional fitness parameters (aerobic, anaerobic, power, speed, etc.) in order to meet the specific functional demands of the playing position, e.g., goalkeeping, defence, midfield, or forwards. Ostojic (2002) further asserted that functional training involves training or practicing the specific demands of a position or role and can be done with a single player or a group of players (forwards, defenders or midfielders). Thus a coach can design and run a specific training session for defence play, addressing specific needs for the defence unit. Ordzhonikidze *et al*. (2007) suggested that for functional training to be effective, it should happen on the soccer field and particularly in that quarter of the field where a specific scenario would be taking place in a real game.

Thus, functional fitness is fundamental in soccer just like in any other sport. For a soccer player to be able to play a ninety minute match, he should possess physical and functional fitness characteristics such as strength aerobic and anaerobic endurance, flexibility, agility and power. (Singh *et al*., 2010; Reiman *et al*., 2009; Campos *et al*., 2004; Ostojic *et al*., 2006). Campos *et al*., (2004) also emphasised that deficiencies and weaknesses in the core muscles of the lower extremities can lead to injury and poor performance during match play.

D. Physical fitness and functional fitness capacity in soccer

Several authors have documented the relationship between physical fitness and functional fitness in soccer (Castagna *et al*., 2010; Reilly *et al*., 2005; Hoff, 2005; Ostojic, 2002; Malina *et al*., 2000; Bangsbo, 1994). They concur that significant relationships are found between measures of physical fitness and functional fitness in soccer skills performance. Sporis *et al*. (2012) examined the relationship between physical and functional capacities and soccer skills performance parameters (defence and attack) of 22 elite junior soccer players selected from a youth club. They used anaerobic (sprint test, repeated sprints, 300m run) and aerobic tests (20m shuttle/beep test, Hoff test) and examined how results from these tests related to soccer skills performance, such as attacking and defending tactics, positioning, ball controlling, shooting and dribbling, preventing and blocking shots, success in off-side trapping and ability to play in multiple positions. They found that both aerobic and anaerobic capacity contributed significantly ($r < 0.61$; $p = 0.03$) to the players' performance in soccer. Furthermore, Hoff's test was found to be a relevant aerobic test in soccer because it incorporates various technical and tactical elements of soccer such as sprinting, dribbling, agility as well as ball controlling. Castagna *et al.* (2010) analyzed the relationship between endurance field tests and match performance in 18 senior soccer players using the Yo-Yo Intermittent recovery test, multistage fitness test (MSFT) and Hoff's test, respectively. Match performance was assessed using the Global Positioning System (GPS). They found that the MSFT and Yo-Yo test were significantly related to performance measurements (distance covered and number of sprints in a match) ($r = 0.62$ and 0.72, respectively; $p = 0.001$). Hoff's test was found to relate to sprinting distance ($r = 0.70$; $p = 0.04$), thus suggesting that this test is more a measure of aerobic capacity. These results show that the Yo-Yo, Hoff and MSFT are valuable tests to assess match fitness and that results obtained from these tests should guide training and exercise prescriptions for youth and professional soccer players.

Diallo *et al*. (2001) examined the physical fitness and technical performance of elite young players according to playing positions and found that forwards covered significantly less distance in a match compared to midfielders and defenders ($p < 0.001$), but performed more sprint bouts in a match than goalkeepers, defenders and midfielders ($p < 0.001$). The findings concur with Impellizzeri and Marcora, (2005) who found that the relationship between physical capacity variables and functional performance were position-dependent. Hence it is advisable that training should be individualized according to playing units (goalkeepers, defenders, attackers and midfielders).

Gil *et al*. (2007) studied 21 professional soccer players from Spain. The aim of the study was to assess the relationship between leg power variables (vertical jump and full squats) and sprint performance. Both tests were found to correlate significantly to soccer sprint times ($r = 0.56$, $p = 0.01$ and $r = 0.79$, $p = 0.01$). Thus explosive power can be an important variable in determining sprint performance.

From these arguments it can be concluded that various physical fitness variables correlate with the functional performance of soccer players. It could therefore be worthwhile for coaches to monitor physical and functional fitness development in youth players as these could be indicative of their future success as professional players.

E. Physical fitness indicators in soccer

Several researchers in soccer have tried to evaluate factors that optimally contribute to successful soccer performance (Svensson and Durst, 2005; Wisløff *et al*., 1998; Tumilty, 1993; Carter, 1985). Factors that have been considered and studied include physical, physiological and anthropometric variables such as aerobic and anaerobic capacity, speed, muscular strength, agility, power, flexibility, body mass and percentage body fat (Svensson and Drust, 2005). Other factors that are important, but are more difficult to measure and quantify are; level of skill (Hoff, 2005; Reilly, 2000a) and degree of motivation, as well as playing tactics used against opponents (Reilly *et al*., 2000a). According to Reilly *et al*. (2000b) the most discriminating variables among elite and non-elite soccer players are agility, sprint time, aerobic capacity, and anticipation skills. Gravina *et al.* (2008) included fatigue tolerance and ability to dribble the ball as relevant successful performance indicators.

The following physical fitness components were identified as major contributors to soccer skills performance (Castagna *et al*., 2013; Sheppard and Young 2006; Hoff, 2005; Svensson and Durst, 2005; Helgerud *et al*., 2001; Reilly, 2000a; Wisløff *et al*., 1998; Tumilty, 1993).

1. Aerobic capacity

Soccer is a high intensity intermittent sport and therefore requires high levels of both aerobic and anaerobic capacities. However, since more than 90% of the energy cost during a football match is provided by the oxygen dependent energy system (Hoff and Helgerud, 2003) one can assume that aerobic capacity is perhaps the most important variable of the two. Maximum oxygen capacity (VO2max) is a widely used indicator of aerobic capacity because it indicates the functional limit of the individual's oxygen transport system (Howley *et al*., 1995). VO_{2max} has been used previously to differentiate between successful and less successful soccer teams (Hoff and Helgerud, 2003; Krustrup *et al.*, 2003; Bangsbo *et al*, 1991). Teams with higher aerobic fitness were found to have an advantage over their opponents, by being able to play the game at a faster pace during the course of the 90 minutes (Hoff and Helgerud, 2003; Bangsbo *et al*., 1991). Aerobic capacity is also a determinant of the total distance covered in a 90 minute soccer match ($r = 0.55$; Impellizzeri and Marcosa, 2005; $r = 0.53$, Krustrup *et al*., 2003). Helgerud *et al*. (2001) concluded that this positive relationship between VO_2max movement activities means that teams with superior aerobic capacities will also have increased time in possession of the ball.

Wisløff *et al*. (2004) reported a statistically significant difference in VO_{2max} ($p < 0.05$) in players of the top teams on the Norwegian elite league log table compared to the lowly placed teams. (63.3±4.5 and 58.6±5.2 ml/kg/min). Jankovic *et al*. (1997) found that VO_{2max} can differentiate elite from non-elite and professional from amateur palyers, while Janssens *et al*. (1998) found differences between elite successful and elite less successful players.

On the other hand it is apparent that the more homogeneous the players are the less predictive power VO_{2max} has. Hansen *et al*. (1999) studied 64 soccer players from the English Associations' National School and noted no differences in VO_{2max} (59.3±3.8ml/kg/min) between those who upon graduation sign contracts with professional clubs and those who did not secure contracts.

From the above it can be affirmed that high aerobic capacity has a positive impact on the technical and tactical performance of soccer players and could be used as a predictor of future successful performance in heterogeneous groups at junior level, but it is less discriminating in homogeneous groups, such as players who have been exposed to systematic training at higher levels such as national team level.

In young players, VO_{2max} increase mainly as a result of increases in body size and heart size (Malina *et al*., 2004). The increase in the heart size is associated with an increase in stroke volume, thereby increasing the cardiac output. VO2max increase rapidly up to the age of 13 years in girls and 16 years in boys, after which a steady increase is observed up to late adolescence and adulthood (Malina *et al*., 2004). With increasing age, the differences between boys and girls are more pronounced. In athletes, subsequent variations arise from training status and level of competition. As the level of competition increases, the demand for higher VO_{2max} values also rise. In general, young athletes have lower VO_{2max} compared to their senior counterparts, however, there are some exceptions (Gil *et al*., 2007; Helgerud *et al*., 2001). When using a proper scaling method, it was found that young soccer players have similar VO_{2max} values than senior elite players, although younger players are less economical (Chamari *et al*., 2005).

Table 3.1. VO_{2max} of junior and senior soccer players reported in the literature

Study	Group studied	VO_{2max} (ml/kg/min)
Gil *et al*. (2007).	Spanish elite juniors	62.4 ml/kg/min
Chamari *et al*. (2004).	Tunisian and Senegalese under 19 players	61ml/kg/min
Ostojic, (2003)	Yugoslavian elite seniors	52.9 ml/kg/min
Hoff *et al*. (2002)	Norwegian division 2 players	63.3 ml/kg/min
Helgerud *et al.* (2001)	Hungarian under 18	73.9 ml/min/kg
Puga *et al*. (1993).	Portuguese seniors	60.6 ml/kg/min
Heller *et al*. (1992).	Italian senior national team	63.2 ml/kg/min
Rahkila and Luthanen, (1989)	Finnish under 17 and 18 players	56 ml/kg/min
Leatt *et al*. (1987)	Canadian elite under 18 players	57ml/min/kg

According to Le-Gall *et al*. (2008) it is difficult to separate players already highly selected and exposed to systematic training using VO_{2max}, sprint performance, or anthropometry results. Their assertions concur with Bunc *et al*. (2003) who reported that VO_{2max} for youths and adult players do not differ when expressed in ml/kg/min, however, when expressed in ml/kg$^{0.75}$ /min, there are differences. They also suggested that the difference only lies in the running economy for the two groups, with adults having better economy than youth soccer players. However, Pate and Kriska (1984) stated that VO_{2max} is the best determinant of aerobic endurance capacity and Hoff (2005) contends that lactate threshold and running economy are also important. VO_{2max} can be assessed by both laboratory (treadmill) and field methods such as the Yo-Yo intermittent recovery test (Bangsbo, 1994), the Loughborough shuttle test (Reilly *et al*., 2000a), 20m multi-shuttle/beep test (Aziz *et al*., 2005), Cooper test

(Cooper, 1968), 12 minute run (Astrand and Rodahl, 1986) and Hoff's test (Hoff, 2004). Helgerud *et al*., (2003) argued against field tests, saying that they only have an accuracy of 10-15% hence one cannot distinguish whether improvements in performance are induced by VO_{2max} or running economy. Although Hoff (2004) acknowledged that the most accurate method for measuring VO_{2max}, lactate threshold and running economy is the treadmill test, he argues that treadmill tests do not reflect the actual performance on the soccer field. He asserted that the endurance capacity of soccer players is reflected by their amount of work output during a match, i.e. the distance covered, number of sprints performed and total time spent at different intensities. For this reason he developed a field test to estimate VO2max which included a dribbling track in a situation that simulates the actual game situation. Aziz *et al*., (2005) agreed with Hoff and state that although treadmill tests are considered the gold standard, one must consider that the equipment is expensive and that few soccer clubs can afford it. They further argue that the method is not ideal for soccer teams as it is time consuming and testing the whole team means taking more valuable training time, hence field tests are better suited to their need. Based on the aerobic fitness tests' association to functional performance, these tests can also be considered for talent selection and development.

From the above discussion, it can be noted that the aerobic components is important and contribute significantly to tactical and technical abilities in soccer and coaches should continuously monitor this variables in youth players to enhance their development to elite level.

2. Agility

Running patterns of team sport athletes are characterized by rapid changes in direction, as compared to linear running in track and field athletes (Dawson *et al.*, 2004b; Young *et al.*, 2002; Gambetta, 1996). Agility is the ability of a moving body to accelerate and quickly change direction (Draper and Lancaster, 1985). It is the product of the interaction between speed, balance, strength and coordination (Sheppard and Young, 2006; Farrow *et al.*, 2005). Some authors have described agility to encompass quick movements of the whole-body or certain limbs and quick change of direction (Draper and Lancaster, 1985). Some authorities prefer the term 'quickness' which is used interchangeably with agility and change of direction speed, but which involves some cognitive aspect, visual scanning, decision making and ability to quickly react to a stimuli (Baker, 1999; Moreno, 1995).

Agility can be categorized as planned agility and reactive agility, where the latter is actually similar to quickness. Planned agility describes the deliberate quick change in direction in a straight line along a designed agility course, while reactive agility is when a player moves the whole body rapidly with change of velocity or direction in response to a stimulus (e.g. the movement of an opponent or the ball) (Oliver and Meyers, 2009; Sheppard and Young, 2006; Farrow *et al.*, 2005; Reilly 2000). Reactive agility is a necessity in the game of soccer as the player is required to run with the ball at a fast pace and at the same time avoids being tackled, as well as reacting quickly to the unexpected bounce of the ball and movements of the opponent. Therefore reactive agility can be said to be sport-specific and therefore a number of tests have been designed to test team sport players with a protocol that is functional to their specific sport.

It has been documented that agility can successfully differentiate between athletes of different playing standards in rugby (Farrow *et al.*, 2005), netball (Sporis *et al.*, 2011) and soccer (Sheppard *et al.*, 2006). Sheppard *et al.*, (2006) analysed agility performance of 38 Australian football players, aged 21years using the 8-9 m change of direction speed test (CODST). 24 were classified as a higher performance group and 14 as a lower performance group based on their playing level from the previous season. They found that high performers were significantly superior in terms of agility than lower performers (14.41±0.01 and 15.88±1.2 sec) (p = 0.001). They also noted an intra-group correlation (r= 0.870, $p < 0.05$). They concluded that the agility test was a valid assessment of soccer players at different performance levels.

Young *et al*. (1996) examined elite and non-elite soccer players using the straight line sprint test and Illinois agility test. The results were similar between the two groups for straight line running, however, elite players showed better results in the Illinois test compared to non-elite players (15.3±0.11 and 17.1±2.01), (p = 0.05). These results substantiate the assertion of Reilly *et al.* (2000b) that agility can be used to differentiate between athletes of varying playing abilities.

Various test have been designed to measure agility, for instance, the Buttifant change of direction test (Buttifant *et al.*, 1999), agility 505 test (Svensson and Drust, 2005), agility T-test (Moreno, 1995), the zigzag test (Sporis *et al*., 2011), the 9x4m agility test (Chaleh-Chaleh *et al.*, 2012), the Illinois test (Cureton, 1951) and the 8-9 m CODST (Sheppard *et al.*, 2006). A number of researches have noted that the variation in the length of the agility courses, the narrowness in angles of directional change and the number of turns involved in each test determine the degree of complexity of each test (Young *et al.*, 2001c; Baker, 1999; Buttifant *et al.*, 1999; Young *et al.*, 1996;) and this complexity may contribute in determining the total time taken to complete the test and not the speed of the player. According to Buttifant *et al*. (1999), in discriminating between speed and agility of elite junior soccer players, sprinting speed accounts for only approximately 10% of the performance. The other 90% was attributed to the ‘agility’ of the player, his anticipation skills, his ability to react and decelerate rapidly, as well as the eccentric leg strength. However, the Illinois is commonly used to measure agility of players in sport since it involves both acceleration (straight line sprinting) and directional change.

Table 3.2. Illinois Agility test scores from the literature.

Study	Group studied	Findings
Mercer *et al*. (1998)	Australian juniors	16.54 ± 8.5 sec
	Tunisian juniors	17.7 ± 0.6 sec
Amiri and Fattahi (2013)	Iranian University (23 years)	16.65±4.2 sec
Kutlu *et al*. (2012)	Turkey (Amateur players)	17.54±2.2 sec
	Australian 23yrs	14.08±0.12 sec

Malina *et al*. (2004) asserts that agility increases sharply during the growth spurt in both boys and girls up to the age of 14 years for girls and 18 years for boys. Hastad and Lacy (1994) compared the agility status of young (13-15 years) and late adolescent soccer players (16-19 years) using the Illinois test. They found that young players were between 3%-27% slower compared to older players. The findings reflect a correlation between agility performance and increased age (maturity). They attributed the difference to the ability of older players to accommodate higher training loads and intensities that comes with increase in age. However the other factors such as playing experience, decision making ability and anticipatory skills cannot be ruled out as possible causes of performance difference. Moreno (1995) attributed the difference in agility performance between young and adult players to greater training experience, general strength and lumbo-pelvic stabilisation strength within the adult group, which they suggested are responsible for superior breaking ability, body stability and positioning when completing directional changes at high speeds.

3. Speed

Gambetta (1990) defined speed as the ability to move the body or body segments in the shortest possible amount of time. According to Little and William (2005) sprint speed involves three main attributes namely; acceleration, velocity and speed endurance. Of the three, acceleration and maximal speed are key and necessary for determining the total running performance of an athlete (Duthie *et al.*, 2006a; Little and Williams, 2005). Nesser *et al.* (1996) propounds that sprint tests are commonly used to predict athletic potential during talent identification and to reliably monitor changes in sprinting ability as it develops with maturation and changes in level of competition. According to Malina *et al*. (2004) speed improves greatly between the ages of 5-8 years in both boys and girls, and that gender variations only become apparent during the adolescence growth spurt (14-18 years in boys and 11-14 years in girls). Thereafter speed increases steadily until early adulthood (22 years)

The game of soccer is characterised by low intensity patterns inter-paced with short high intensity sprinting episodes which comprises high speed movements, accelerations, decelerations and recovery periods (Helgerud *et al.*, 2001) and includes walking, jogging, and sprinting (Reilly, 1996; Bangsbo *et al.*, 1991). Wisløff *et al.*, (2004) estimated that the sprinting phase is performed every 90 seconds of play and last between 2-5 seconds, and constitute about 11% of the total distance covered during a 90 minutes match. Although the percentage seems to be insignificant, these periods of play directly contribute to winning of ball possession and creation of scoring chances and are therefore decisive in the final result of a soccer match (Duthie *et al.*, 2005). In any match the attacking and counter-attacking phase demands high speed and acceleration from both strikers and defenders. These actions (attacking and counter-attacking) require a combination of high speed and agility (Little and Williams, 2005). Therefore it is of paramount importance for attackers and defenders to possess high speed abilities.

Many researchers share the opinion that sprint speed improves with level of play (see table 3.2). Studies comparing sprint performances of junior and senior players, elite and non-elite, professional versus amateurs and premier league versus lower leagues, all reported better speed performances for higher level players (Wisloff *et al*., 2004; Cometti *et al.*, 2001; Diallo *et al.*, 2001; Helgerud *et al*., 2001; Kollath and Quade, 1993; Tumilty and Darby, 1992). This variation could be attributed to the level of training and competition demands for each category, the effect of age and maturity as well as the ability of the body to accommodate higher training loads and strength in leg muscles in the case of juniors versus seniors.

Single sprint effort tests over distances ranging from 5 - 60m are regularly used to assess running speed in both junior and senior soccer players (Young *et al.*, 2008; Veale *et al.*, 2008; Duthie *et al.*, 2006a; Pyne *et al.*, 2005). The most frequently used sprint tests are over 10m, 20m, 30m and 40m (Chamari *et al.*, 2004; Wisloff *et al*., 2004; Hoff and Helgerud, 2002; Cometti *et al*,. 2001; Kollath and Quade, 1993) with less frequent use of 5m, 15m and 60m, (Dupont *et al.*, 2005; Helgerud *et al.*, 2001). This tendency is in line with the argument of Valquer *et al*. (1998) who reported that 96% of sprint bouts in a soccer match are of less than 30m and at least 49% of these are less than 10m.

Hoff (2005) noted that straight line speed tests only focus on aspects such as; when players run in to meet the ball; chasing opponents or run to cover space, but overlook the aspect of running with the ball. He therefore suggested that speed testing in soccer should also involve testing players' ability with the ball. To this end Reilly (2001) designed a test battery for monitoring young soccer players which involves maximum speed sprinting over a zigzag course of 9-14m whilst dribbling the ball. This test incorporates many aspects of soccer performance such as dribbling skills and agility, as well as speed. The test was subsequently approved for talent identification programmes by many soccer clubs. From this test battery

Reilly (2001) was able to distinguish successful from non- successful performers in skills such as speed, agility, ball control and dribbling.

Cometti *et al*. (2001) measured ninety five (95) French elite and sub-elite soccer players with the aim of finding the appropriate test that could discriminate between players' performances. Elite players had shorter 10m sprint time compared to sub elite players (1.79 sec versus 1.90 sec; $p < 0.05$), but there was no difference in 30m sprint times for the two groups. These results imply that a 30m sprint test is not a good test to distinguish between different levels of players. Similarly, Stolen *et al*. (2005) reported that speed over 10m and 20m are good indicators of on-the-field performance and that these results can distinguish good performers from lesser performers. These observations concurs with Valquer *et al*. (1998) who noted that 5m, 10m and 20m sprint tests better resemble the actual short sprint bouts in the real game of soccer.

Young *et al.* (2005) compared starters and non-starters of elite Australia club players using 10m and 40m sprint tests. The aim of the study was to determine whether speed can be used to select players who enter as starters or substitutes in a match. They reported a significant difference between the two groups ($p = 0.02$). Starters scored 1.86±0.06 seconds in 10m sprint and 3.46±0.06 in 40m sprint against 1.94±0.09 and 3.57±0.13 seconds for non-starters. Pyne *et al.* (2005) measured sprint speed (5, 10 and 20m) of junior players selected for the final end of season draft camp in Australia and who were successfully selected into the elite senior team and those who were not selected. They found that those who were selected performed better compared to the non-selected. However, Veale *et al.*, (2008) used 10, 20 and 40m sprint and noted that there was no difference ($p = 0.16$) between sprinting performance of players selected into the senior team and those who were not selected. This could be that the group studied was more homogeneous that they performed at similar level.

The majority of studies therefore indicated that sprint speed tests can successfully discriminate between players from a heterogeneous group and can be used to distinguish between talented and less talented soccer players.

Table 3.3. Speed test scores reported in the literature

		Sprint performance in seconds				
Study/country	**Level**	**5m**	**10m**	**20m**	**30m**	**40m**
Diallo *et al*, (2001) France	12-13 years			5.56±0.10		
Kollath and Quade, (1993). Germany	Pro	1.03±0.08	1.79±0.09	3.03±0.11	4.19±0.14	
	Am	1.07±0.07	1.88±0.10	3.15±0.12	4.33±0.16	
Chamari *et al.* (2004). Tunisia and Senegal	Jnr		1.87±0.1		4.38±0.18	
Cometti *et al.* (2001). France	D1		1.80±0.06		4.22±0.19	
Helgerud *et al* (2001). Norway	Jnr		1.88±0.06			5.58±0.16
	D1		187±0.06	3.13±0.10		
Hoff and Helgerud (2002). Norway	D2		1.91±0.07			5.68±0.21
Brewer and Davis (1992). England	Pro					5.51±0.13
Wisloff *et al*. (2004) Norway	D1		1.82±0.30	3.00±0.30	4.00±0.20	

Pro-professional; Jnr-junior; Snr Nat-senior national team; D1-division 1; D2-division 2; Am-amateur

4. Power

The significance of strength and power in many sports is widely reported (Abernethy *et al*., 1995; Wilson *et al*., 1995; Bloomfield *et al*., 1995). Power refers to the ability of the neuromuscular system to produce the greatest possible impulse in a shortest period of time.

The duration of the impulse depends on the resistance or the load against which the athlete has to work on (Schmidtbleicher, 1992). Athletes in most team sports are required to make high power output movements which they are required to sustain during the course of the activity (Amusa and Toriola, 2003). The total power an athlete can produce is determined by the ability of the athlete's anaerobic system to split high energy intramuscular phosphagens through anaerobic glycolysis (Plowman and Smith, 1999). Soccer players often perform episodes of jumping especially when heading the ball, jogging, sprinting and throwing. All these activities require some degree of force generated from the upper or lower limbs.

Several dynamic actions performed in team sports depend on leg power, e.g. jumping, sprinting, kicking, heading the ball and jogging (Little and Williams, 2005; Faigenbaum and Westcott, 2000). All successful movements depend to a certain degree on the muscular power of the legs (Faigenbaum and Westcott, 2000) and has been shown to be important in basketball (Makaza, *et al*., 2012; Ostojic *et al*., 2009), netball, (Terblanche and Venter, 2009; Faigenbaum and Westcott, 2000); soccer (Castagna, 2013; Malina, 2005; Reilly, 2000) and rugby (Gabbett, 2005). Gray and Jenkins, (2010) propound that the bumping, tackling, and tussling activities that take place when contesting and marking the ball in soccer require high levels of lower and upper body power. This therefore means that leg power is essential to soccer performance in all playing positions and coaches should purposefully work to improve this component during training sessions.

Vertical jump and standing horizontal jump tests are commonly used field tests to assess lower limb explosive power (Aragon-Vargas, 2000). Many researchers prefer the use of vertical jump height, rather than horizontal jump distance as the better method to measuring explosive leg power in soccer players (Chaleh-Chaleh *et al*., 2012; Stolen *et al*., 2005; Reilly, 2000; Malina *et al*., 2004), because most of the jumping actions in soccer are performed vertically rather than horizontally. The primary objective in a vertical jump in soccer is to reach the furthest vertical height possible to intercept the path of the ball. Due to the importance of this movement in a soccer match, the ability of a player to perform a vertical jump is often considered an indicator and predictor of future performance in talent identification efforts (Chaleh-Chaleh *et al*., 2012; Psycharakis, 2011; Reilly, 2000). Vertical jump performance is also linked to muscular coordination (Malina *et al*., 2004) and sprinting velocity (Kale *et al*., (2009) and Arnason *et al*. (2004) asserted that it is also a good measure of functional performance in the field as it is a good resemblance of the actual jumping action in a soccer match.

In soccer the ability to jump higher than opponent has an advantage to players who play in the attack and defence positions where scrambling for the ball when it is high. Reilly (2000) noted that good jumping ability gives an advantage to the goalkeepers too, when catching high balls especially when faced with taller strikers. Players with greater jumping abilities reach for high balls first and will head high balls which cannot be intercepted by opponents (Young *et al*., 2007; Gerodimos *et al*., 2006;) and therefore they win possession more than those with low jumping capacity (Ashley and Weiss, 1994). For these reasons the vertical jump test has emerged as the preferred method of assessing jumping capacity in soccer (Reilly, 2000; Kellis *et al*., 1999; Bangsbo, 1994). However, like most functional tests, it may underestimate the athlete's true potential if he or she does not perform the test with the most suitable technique (Wakai and Linthorne, 2005).

Jumping performance (vertical and horizontal) increases with age up to 14 years for girls and 18 years for boys and thereafter it increases more steadily up to adulthood (Young *et al*., 2007; Gerodimos *et al*., 2006; Malina *et al*., 2004). Slow increases in jumping performance in girls can be attributed to the accumulation of fat mass, particularly during adolescence. Age does not contribute much on jumping performance at adulthood. This was substantiated by Gerodimos *et al.* (2006) in a study to evaluate leg power generating capacity of the extensor muscles group in elite Greek youth soccer players and its differentiation over age (Table 3.3). They observed that the increase in power generating capacity of the extensor muscles was not significant until the age of 13 years. Thereafter there was an abrupt increase in jumping ability of 13-21% from 13-17 years of age and at adulthood age played no role on the differences in jumping ability. This observation corresponds with those of Malina *et al*., (2004) who observed a vertical jump performance variation (37±0.01 and 47±0.09cm) between 12 and 17 years soccer players from Norway. The variation was attributed to growth and muscular development (Malina *et al*., 2004), as well as to the interrelationship between factors such as age, height, body mass, maturation, muscle size and training (Loakimidis *et al*., 2004; Malina *et al.*, 2004; Gerodimos *et al.*, 2003; Kellis *et al*., 2001 Hansen *et al*., 1999; Blimkie, 1989).

Table. 3.4. Vertical jumps scores reported in the literature.

Study/country	**Level**	**Findings**
Gerodimos *et al*. (2006). Greece	Juniors (10-12years)	37.7±0.01cm
	Juniors (16-17 years)	47.5±0.09 cm
Leatt *et al*. (1987). Canada	Juniors (16-18)	53±0.33 cm
Wisloff *et al*. (2004). Norway	Under 18	56.4±0.4 cm
White *et al*. (1988). England	Under 19	59.8±5.1cm
Helgerud *et al*. (2001). Norway	Division 1	60.2±3.4 cm
Tiryaki *et al*. (1997). Turkey	Elite	64.8±0.2 cm
	Division 2	54.1±1.2 cm

5. Flexibility

Flexibility, according to Eston and Reilly (1996), is defined as the range of motion (ROM) at a single joint or series of joints. Gleim and McHugh (1997) considered flexibility as a component of physical fitness and defined it as the amount of movement of a joint through its normal plane of motion. There is also a distinction between static and dynamic flexibility. Static flexibility is defined as the range of motion available to a joint or series of joints (Gleim and McHugh, 1997). Dynamic flexibility refers to the ease of movement within the obtainable range of motion (Maud and Cortez-Cooper, 1995). Sub optimal flexibility increases the risk of injuries. Therefore testing for flexibility can be important in soccer as it can possibly identify players at risk (Ostojic and Stojanovic, 2007; Reilly, 1996). Arnason *et al.* (2004) analysed the frequency and severity of injury and its relation to performance in top English soccer teams and found that teams who sustain fewer injuries occupied better positions on the log standings and had greater chances of success at the end of season. This observation may relate to the findings of Gleim and McHugh (1997) who reported that non-injured groups of players tend to be more flexible than injured groups.

Several studies have shown that soccer players have poorer flexibility than non-athletes (Signorelli *et al*., 2012; Ostojic and Stojanovic, 2007; Malina *et al*., 2004) which could be associated to the little attention given to flexibility during training sessions as most coaches would rather focus on skills training and game strategies. Ostojic and Stojanovic (2007) compared the flexibility of thirty (30) elite (national league players) and thirty (30) non-elite (Division 3 players) Serbian soccer players. The purpose of the study was to examine the relationship between flexibility and level of play. They found no significant differences between elite and non-elite players in passive hip flexion and ankle flexibility ($p > 0.05$). A significant difference was noted in sit and reach results, non-players had superior scores compared to elite players (10.7±6.4 and 7.9±3.2), ($p < 0.05$). Young and Pryor (2007) examined the flexibility scores of 485 young elite and non-elite Australian soccer players using the sit and reach method. They observed that elite players had higher scores compared to non-elite players (8.8± 7.5 and 7.1 ±7.3 cm), ($p = 0.039$), and this higher score cannot be interpreted to mean the best suitable score.

Varying flexibility scores have been reported by different authors (Table 3.4). Young and Pryor (2007) and Ostojic and Stojanovic (2007) reported higher scores for Australian and Serbian elite than non-elite youth players. Generally it is expected that players at higher levels of play should have better fitness characteristics and should perform better than those at lower levels of play. This is true for most fitness characteristics, but not for flexibility; in this case higher level players do not necessarily have better flexibility and in fact, many studies actually show they have poorer flexibility than lower level players. This suggests that level of flexibility should have little effect on talent selection, since it cannot discriminate between elite, professional and selected players from non-elite, non-professional and non-selected players. Although flexibility is important in all sport, it affects performance in individual sports more than in team sport.

Table 3.5. Sit and reach flexibility scores in the literature

Study	**Group studied**	**Findings**
Gray and Jenkins (2010) Australia	Professionals	10.7±6.4cm
Young and Pryor (2007) Australia	Elite juniors (selected)	8.8± 7.5cm
	Non-selected	7.1 ±7.3cm
Raven *et al*. (2012) North America	Professionals	22.9± 1.2cm
Raut (2012) India	Seniors	13.73±3.8cm
Ostojic and Stojanovic (2007) Serbia	Elite national league	29.1± 4.7cm
	Division 3	36.4 ± 5.2cm
Signorelli *et al*. (2012) Brazil	Young elite	14.3±3.2cm
	Young non-elite	13.1±4.4cm
Nikolaïdis (2012) Greece.	Under 12	16.6±5.1cm
	Under 16	20.7±7.5cm
	Adult players	24.7±6.9cm

Flexibility has been shown to decrease with increased age in boys from 5-11 years and then rapidly increases at adolescence growth spurt until the age of 18 (Malina *et al*., 2002). Adolescence growth spurt is characterized by increases in leg length and shorter trunk length and this leads to less flexibility. In girls the trunk is generally longer than the legs; hence the better flexibility in girls than in boys. Signorelli *et al*. (2012) compared the flexibility of young (17-22 years) and older (27-36 years) players from elite soccer clubs in Brazil to investigate the effect of age and maturity on pre-season flexibility. They found that flexibility has an age-related decrease, although the difference was not statistically significant between the two groups (14.3±3.2 versus 13.1±4.4 cm; p = 0.11). They attributed the difference to age-related loss of muscular elasticity.

It can be concluded that level of play may not influence flexibility and that age-related increases in flexibility occur from late adolescence to early adulthood; thereafter there is an age-related decline in flexibility.

F. Relationship between functional fitness variables in soccer

Performance in soccer is dependent on aerobic and anaerobic fitness, speed, muscular strength, flexibility, power and agility (Sporis *et al*., 2011; Bangsbo *et al*., 2006; Stolen *et al*., 2005; Reilly, 2005). It is therefore expected that some of these fitness would also be inter-related. Pauolf *et al*. (2000) reported a significant correlation (r = 0.67) between performance in the agility t-test and 40 m sprint time in both male and female soccer players.

Parnou *et al*. (2005) found a very strong relationship between agility (T-test) and 10m speed in National footsal players (r = 0.887), but a weak correlation with 20 m sprint (r = 0.223). Considering the game of soccer, the explosive sprint bouts during match play more resembles 10m sprints than 20m sprints and therefore this finding is not surprising. Sporis *et al*. (2011) determined the relationship between speed, agility and quickness (SAQ) among 25 elite Serbian under 16 National team soccer players according to playing positions. Speed was tested using 10m, 20m and 30m flying sprints and agility and quickness was tested using a zigzag test with and without the ball to assess the ability of players to control the ball while changing direction along a zigzag course. They observed that players of different playing positions do not differ significantly in the variables tested (speed and agility). They reported that attackers displayed more quickness, while goalkeepers were the slowest. Attackers also showed best results in agility and speed with and without the ball than other players. The results showed a significant positive correlation between speed (20m and 30m) and agility (r = 0.603 and 0.560), respectively. No significant relationship was observed between agility and 10m sprint. These findings differ from those reported by Parnou *et al*. (2005) who found significant relationship between agility and 20m sprint speed on Iranian National footsal players. The probable reason for these differences could be the methods that were used in the 2 studies to test agility. The T-test offers subjects a wider and easier angle of directional change of close to 100^0 compared to the zigzag method which offers between $45\text{-}70^{0.}$ Thus, the subject turns fast in T-test and gives better results than in zigzag test where turning is slow giving poor results. In zigzag test more time is lost due to many decelerating and re-accelerating point.

Agility with the ball was found not to correlate with speed and quickness for all groups (r = 0.09). Chaleh-Chaleh *et al*. (2012) examined the relationship between speed, agility and anaerobic power of 20 elite Iranian junior soccer players between 14-16 years. The Sargeant vertical jump test was used to assess the anaerobic power of subjects, 10m sprint test was used to assess speed and agility was assessed using a 9x4m test. They found a statistically significant relationship between explosive power of the legs and linear speed (r = 0.904, p = 0.001), between anaerobic power and agility (r = 0.884, p = 0.001), as well as between linear speed and agility (r = 0.976, p = 0.001). They concluded that these anaerobic variables (speed, agility and power) are very important in soccer and coaches should pay particular attention to these factors during training to improve players' performance.

G. Summary

From the related literature reviewed in this section one can conclude that success in soccer depends on the interaction between various anthropometric and functional fitness variables such as weight, height, strength, aerobic, anaerobic capacities, flexibility, speed, agility, power, coordination, blended with other factors such as level of experience, technical and tactical skills development, as well as some psychological factors like level of motivation. Some of these factors are genetically acquired, e.g. height, and cannot be altered through training, while some are phenotypic-they are gained through training and nutrition, such as body size, aerobic and anaerobic fitness, flexibility etc. However, factors such as weight, speed, aerobic and anaerobic fitness can be a result of the interaction between genotypic and phenotypic factors. This shows that no one single variable can be singled out as the defining principle which will guarantee success in soccer but that it is rather a combination of factors that contribute to elite performances. Thus profiling of players is essential in assessing player's capabilities, level of fitness and skill acquisition. Anthropometric and physiological profiling provides sport scientists and coaches with better tools to predict players' potential for future success as an elite player.

CHAPTER 4

PROBLEM STATEMENT

A. Introduction

Whilst body fat is essential to health, excess body fat is detrimental to athletic performance in sports which require body weight transference and support over a distance such as track and field athletics and team sport (Singh *et al*., 2010; Ostojic, 2003; Carter and Heath, 1990). Body composition measurements also help to correctly classify athletes in sport such as boxing, wrestling and gymnastics which demand specific weight categories. Therefore the appraisal of body composition provides norms by which sport specific measures can be determined and maintained. A soccer player wishing to participate in a ninety minutes match he should have optimal physical and functional fitness characteristics such as aerobic and anaerobic endurance, strength, agility and power. Lack of these qualities in a player leads to poor performance and increased risk to injuries (Reiman *et al*., 2009; Ostojic 2002; Campos, *et al*., 2004).

B. Summary of literature

A number of research studies share a similar view that there is a correlation between body composition and functional performance in soccer (Singh *et al*., 2010; Fields and Goran, 2000; Sinning, 1996; Bloomfield *et al*., 1995). In discus, shot put, hammer throw, wrestling, rowing and boxing, high fat free mass is necessary to achieve successful performance. In track athletics, gymnastics, and most team games, leanness increases the chance to succeed (Singh *et al*., 2010). Toriola *et al*. (1985) emphasized the importance of appropriate morphological components (body size, shape and proportion) of athletes as additional considerations in sport performance which should be supported by appropriate sport-specific training to achieve success in sport.

Abraham (2010) noted that the appropriate somatotype for athletes such as runners, jumpers and gymnasts are generally ectomorphic and those in team sports are mesomorphic. Throwers in shot put, discus and hammer events are usually categorized as mesomorphic-endomorphs or endomorphic-mesomorphs and were found to possess significantly higher BMI and skinfold values meaning which means they have higher subcutaneous adiposity (Singh *et al*., 2010; Bloomfield *et al*., 1995; Carter and Heath, 1990; Thorland *et al*., 1983). In general, the consensus is that the ideal body composition for a sports person consists of high FFM and low FM (Abraham, 2010; Singh *et al.*, 2010; Bloomfield *et al*., 1995; Marfell-Jones 1991; Carter and Heath, 1990; Thorland *et al*., 1983).

Several authors have documented the relationship between physical fitness and functional performance in soccer (Castagna *et al.,* 2010; Reilly *et al*., 2000b; Hoff, 2005; Ostojic, 2002; Malina *et al*., 2000; Bangsbo, 1994). They concur that significant relationships are found between measures of fitness and functional performance in soccer in both young and adult players and that some functional performance variables are important for use during talent identification as they can discriminate successful from less successful performers (Castagno *et al*., 2013; Chaleh-Chaleh *et al*., 2012; Sporis *et al*., 2012; Impellizzeri and Marcora, 2005; Reilly *et al*., 2005; Svensson and Durst, 2005; Stollen *et al*., 2005; Hoff and Helgerud, 2002; Reilly, 2000; Wisløff *et al*., 1998; Tumilty, 1993). For instance, VO_{2max} has been reported to positively correlate to the total distance covered by players, number of sprints performed by a player in a match, as well as the amount of time a team spend in possession of the ball before it is taken by the opponents. Jankovic *et al*. (1997) pointed out that this single variable,

VO_{2max}, can distinguish elite from non-elite players, professional from amateurs, as well as successful from less successful team players.

Sprint speed was found to be influential in predicting athletic potential during talent selection in youth soccer players and these tests can be reliably used to monitor changes in sprinting ability due to maturation and changes in level of competition throughout the athletes' growth curve (Malina *et al*., 2004; Wisloff *et al*., 2004; Cometti *et al.*, 2001; Diallo *et al.,* 2001; Helgerud *et al*., 2001; Nesser *et al.*, 1996; Kollath and Quade, 1993). A review of various research studies in soccer revealed that 10m, 20m, 30m, and 40m speed tests are the most common test applied in soccer (Chamari *et al.,* 2004; Wisloff *et al*., 2004; Hoff and Helgerud, 2002). Leg power was also found to be important in soccer because several actions performed by players during a soccer match (jumping, sprinting, kicking, heading the ball and jogging) depend either directly or indirectly on leg power (Little and Williams, 2005; Faigenbaum and Westcott, 2000). Furthermore, leg power can also be used to discriminate players of different playing standards and was found to correlate to maturity status. Thus mature players perform better compared to young players, hence it can be used in talent selection (Baker, 1999; Moreno, 1995).

Some studies suggest that the athletic population actually has weaker flexibility than non-athletes, but that young athletes have better flexibility than older athletes. Thus there is a negative relationship between flexibility and performance (Signorelli *et al*., 2012; Ostojic and Stojanovic, 2007; Malina *et al*., 2004). This means that although flexibility is important to athletes in terms of possible injury prevention, it has little importance in talent selection.

C. Motivation for the study

An understanding of body composition and physiological characteristics of athletes helps coaches and sport scientists to know the optimum physique required to meet the demands of a particular sport and to determine variables that are key to talent identification and those that predict future successful performance in young players. Ostojic (2003) observed that lack of physique in soccer can contribute to poor performance. Therefore an understanding of the anthropometric profile and functional capacity of junior soccer players could give coaches and trainers better working knowledge to identify and select talent, monitor growth and achieve success in the game.

The science of body composition, somatotype and functional fitness assessment play a vital role in the selection of junior players, it can help to determine the preparedness of players to accommodate certain training loads and assess players' response to training, enhance prediction of future success in young players and help to determine possibilities of competition success. This science is currently scant in African soccer. Underhay *et al*. (2005) propound that, carrying out a scientific study of sports persons from Africa is valuable, as such research would impact positively on the scientific coaching, selection and development of talent and general support for athletes and coaches. Without an understanding of the growth of youth and their functional and structural evolution, selection of talent and monitoring of training is largely a matter of sophistry and illusion (Willmore and Costill, 1999). Motivated by these assertions, undertaking a research study in this field would help soccer coaches to adopt more scientific approaches to training and potential players can be recruited via talent identification programmes.

A plethora of research is available on body composition, morphological and functional characteristics of players in various sporting disciplines and for different countries. However, literature that compares body composition and functional capacity of young soccer players from African countries of different races is limited. Only two studies was found that analyzed young soccer players from South Africa and Zimbabwe respectively, but they focused only on body composition. No literature was found on the functional fitness capacities of young players from these two countries. This study is therefore the first to examine body composition, somatotype and functional fitness of young players from South Africa and Zimbabwe. Therefore this research study is going to be a foundational platform for other researchers in the field who may take an interest in studying these two countries.

D. Aim of the study

- The principal aim of the study is to compare body composition, somatotype, and functional fitness characteristics of young academy soccer players in South Africa and Zimbabwe.

E. Specific aims of the study

- To compare body composition, somatotype and functional fitness characteristics of South African and Zimbabwean junior soccer players according to playing positions.
- To compare the anthropometric, somatotype and fitness characteristics of South African and Zimbabwean junior players to international standards of the same age group.
- To distinguish variables that can be used for talent selection in soccer
- To explore the relationship between body composition and fitness variables in young soccer players.

CHAPTER 5

METHODOLOGY

A. Introduction

The major objective of the research study was to explore distinctive anthropometric, physical and functional performance characteristics of junior academy soccer players, which can be used to predict their future success in soccer and to compare those results to the test scores from other countries around the world. It is assumed that by realizing this objective, this study could subsequently add value to talent identification and nurturing processes as well as in monitoring players' physical and functional performance.

B. Research design

The study followed a quantitative non-intervention method with a sample of convenience. The study assumed an exploratory approach which can be used to predict young players' future success in soccer. A comparative approach was also used in the sense that the research compares participants from South African soccer clubs and those from a Zimbabwean soccer academy. It also compares the research data of young players from these two countries to results of similar studies in the rest of the world.

C. Research participants

The research participants were purposively selected, however, each individual had the opportunity to either volunteer for the study, or decline participation. A total of 74 players participated in the study. 41 were selected from South African teams and 33 players were selected from Zimbabwean teams. The study included only players from selected academies in South Africa and Zimbabwe who volunteered to participate. Players who were nursing injuries and those who fell ill on the testing day were excluded from participation.

1. The Zimbabwean players

Thirty three players from the Zimbabwean teams volunteered to participate in the study. Seventeen (17) played in the Zimbabwe Football Association first division which is similar in status to the Mvela league of their South African counterparts. This is a very competitive Zimbabwean league in which the winner at the end of the season gets promoted to the National Premier Soccer League (PSL). The remaining sixteen players play in the Harare Region Junior League. The Zimbabwean players had at least 4 years of exposure to organised soccer. The first 17 players stay and play together as a team both at school and at the club. Three of the players play for the Zimbabwe National under 17 team, while the rest of the players feature in senior and junior school teams. The other sixteen stay at different places and go to different schools but play for a regional junior league of their age group. All the Zimbabwean players train four days per week and they play league matches over the weekends. The average age of the Zimbabwean players was 16.5±0.70 years. 73% were late maturers and 27% were considered on-time maturers. The team comprised of 5 goalkeepers; 7 defenders; 11 midfielders; and 10 forwards/strikers.

2. The South African players

The South African teams play in the Western Province junior league. The players do not attend the same schools and they only meet during training sessions twice per week. The average age of the South African players was 16.4±0.94years. 80% were late maturers and 20% were considered on-time maturers. The sample consisted of 5 goalkeepers; 14 defenders; 12 midfielders; and 10 forwards/strikers.

D. Assumptions

It was assumed that players will not consume either excessive or very minimal amounts of water at least two hours before the anthropometric tests. It was also assumed that the players will not train or partake in any vigorous exercises at least 24 hours before the testing day. It was further assumed that all players will give their best effort in all the tests.

E. Limitations

The study sample was selected through a non-random sampling technique and was not representative of all junior soccer players in South Africa and Zimbabwe. The anthropometric and functional capacity tests were collected on different dates for the teams.

F. Delimitation

The research study was limited to the under 17 soccer players in South Africa and Zimbabwe and cannot be generalized to any other group.

G. Ethical considerations

The research protocol was approved by the Ethics Committee for Human Research at Stellenbosch University (DESC_Masocha2012). Permission was first sort from the club directors before players were approached and introduced to the research project. All players and parents were informed of the test protocols and were offered the opportunity to voluntarily participate. Each player signed an assent form and parents/guardians signed consent forms on behalf of the participants who were all below the legal age of majority. Only those players who brought back signed consent and assent forms were included in the study. It was made clear to all players that there would be no penalty if they choose not to participate in the study, and that their involvement (or not) in the project would not affect their eligibility to play for the team. They were also reminded that they could end their participation at any time, without penalty. No invasive test procedures were used and none of the tests posed any serious risks to the participants.

H. Data collection

The tests were conducted at the end of October 2012 and mid May 2013 for Zimbabwean players and March 2013 for South African players. The testing process started early in the morning until midday and were conducted at the clubs' gymnasia and training fields. Anthropometric measurements were carried out first, followed by the physical tests. According to the recommendations of Gore (2000), the following testing order was observed:

- Body mass and height.
- Skinfolds – (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf.)
- Girths – (arm relaxed, arm flexed and tensed, waist, gluteal, and calf.)
- Bone breadths – (biepicondylar humerus and biepicondylar femur), sit and reach, shoulder flexibility, vertical jump, horizontal/standing long jump.

Field tests were conducted on day two of testing in the following order:

- Overhead throw.
- Speed tests
- Agility test
- Hoff's aerobic fitness test.

The test protocols for the study were selected in accordance to the literature (Ostojic 2003; Reilly, 2000; Bangsbo, 1994; Tumilty, 1993). This was done so that the results of the study could be evaluated against those from similar international research studies. All the standard testing protocols were observed during the testing process.

During anthropometric testing, the participants wore tights and during the field tests they put on their training kit and soccer boots.

I Measurements and testing procedures

1. Landmarking and skinfolds

All anthropometric variables were measured using the standard procedures of the International Society of the Advancement of Kinanthropometry (ISAK) (Marfell-Jones *et al.*, 2006). The anthropometric sites and descriptions that were used in this study were based on those propounded by Ross and Marfell-Jones (1991) and Norton and Olds (1996), ratified by the International Society for the Advancement of Kinanthropometry (ISAK) and revised by Marfell-Jones *et al.*, (2006).

Landmarks are identifiable skeletal points which generally lie close to the body's surface and are the markers which identify the exact location of a skinfold measurement site or from which a soft tissue site is located. These landmarks are found through palpation or by measurement (Marfell-Jones *et al.*, 2006).

Landmarks were identified using the thumb and the index finger. The identified site was then marked with a small cross (+) using a fine tipped demographic pen. The mark was then re-confirmed to ensure that there has no skin distortion or displacement of the skin relative to the underlying bone. All landmarks were identified after measurements of height and weight were taken. The following landmarks were identified and in this order: acromiale, radiale, mid-acromiale-radiale, triceps skinfold site, biceps skinfold site, subscapulare, subscapular skinfold site, iliocristale, iliac crest skinfold site, iliospinale, supraspinale skinfold site, abdominal skinfold site, medial calf skinfold site and front thigh skinfold site. As a right thumb rule, all skinfold measurements were taken on the right side of the body (Marfell-Jones *et al*, 2006). Measurements were taken in the morning before mid-day when environmental temperatures were still low, and the time of testing was recorded on the data sheet. Two anthropometric measurements were taken (by one person) at each site and an average was recorded except for bone breadth. In the event that a variation of more than 0.5 mm was observed between two measurements, a third measurement was taken and the middle value was recorded as final.

2. Stretch stature (height)

Height is the perpendicular distance between the transverse planes of the vertex and the inferior aspect of the feet (Marfell-Jones *et al.*, 2006). Height was measured using a Gima stadiometer (Gima®-Itally. Subjects stood in a perpendicular position with the heels, buttocks and upper part of back in contact with the scale and the head positioned in the Frankfort plane. The measurer placed the headboard firmly down the vertex, crushing the subject's hair as much as possible while the assistant gently applied a lift at the mastoid process. The height was recorded to the nearest 0.1 cm.

3. Sitting height

Sitting height is the maximum distance from the vertex to the base of the sitting surface. The subjects were seated on a measuring box with an even surface and with the head in the Frankfort plane. The assistant gently applied an upward lift through the mastoid process while the measurer took the height using a stadiometer. The subjects were advised neither to contract the gluteal muscles nor to push up with their legs**.**

4. Body mass

Mass is the quantity of matter in a body and is calculated through the measurement of weight. Body mass was measured using a Gima digital scale (Gima®-Italy). Body mass was recorded to the nearest 0.1kg. Values for height and weight measurements were used to compute body mass index (BMI).

5. Skinfolds

A total of eight skinfolds were measured using skinfold Slimguide callipers (Rosscraft®-Canada) and a demographic pen for the landmarks. The following skinfolds measurements were taken according to the methods of Marfell-Jones *et al.* (2006): triceps, subscupular, biceps, iliac crest, supraspinale, abdominal, front thigh and medial calf.

6. Triceps skinfold

Objective: To assess triceps skinfold thickness from the vertical fold of the skin on the posterior side of the arm on the triceps muscle.

Method used: The subject stood in the anatomical position, with arms hanging by the side in a relaxed position. Firstly the mid- acromiale-radiale was identified using the anthropometric tape and a demographic pen. The triceps skinfold site was marked on the posterior surface of the arm on the triceps muscle line and at the level of the marked acromiale-radiale skinfold landmark. The shoulder joint was externally rotated to mid-prone position. The skinfold measurement was taken parallel to the long axis of the arm at the marked site.

Trials: Two measurements were taken and the average was recorded as the final score.

7. Subscupular skinfold

Objective: To assess the subscapular skinfold thickness from the natural fold of the skin along the lower tip of the subscapular.

Method used: The subject stood in an anatomical position, relaxed and arms hanging on the sides of the body. The measurement was taken with the folds running obliquely downwards at the subscapular skinfold site along the natural fold of the skin.

Trials: Two measurements were taken and the average was recorded as the final score.

8. Biceps skinfold

Objective: To assess the biceps skinfold thickness that is the thickness of the vertical fold of the skin taken on the biceps muscle at the level of the acromiale-radiale landmark.

Method used: The biceps skinfold measurement was taken at the biceps skinfold site and parallel to the long axis of the arm at the biceps. The subject assumed the anatomical and relaxed position. Arms were hanging and relaxed while the shoulder was externally rotated with the elbow extended by the side of the body.

Trials: Two measurements were taken and the average was recorded as the final score.

9. Iliac crest skinfold

Objective: To assess the iliac crest skinfold that is measured near-horizontally at the iliac crest skinfold site, immediately above the marked iliocristale.

Method used: The iliac crest skinfold was measured almost horizontally at the skinfold landmark. The subject stood in an anatomical position in a relaxed manner. The right arm crossed over to the chest.

Trials: Three measurements were taken and the average was recorded as the final score.

10. Supraspinale skinfolds

Objective: To assess the supraspinale skinfold from a double fold of skin and underlying subcutaneous tissue at the supraspinale skinfold.

Method used: The skinfold was measured at the supraspinale skinfold site, with the fold running obliquely and medially, downwards and anteriorly at an angle of 45^0 as determined by the natural fold of the skin.

Trials: Two measurements were taken and the average was recorded as the final score.

11. Abdominal skinfold

Objective: To assess the abdominal skinfold measurement taken from a double folds of skin and underlying subcutaneous tissue at the abdominal skinfold site.

Method used: The subject assumed an anatomical position, relaxed with arms hanging by the sides of the body. The abdominal skinfold was measured vertically at the abdominal skinfold site.

Trials: Two measurements were taken and the average was recorded as the final score.

12. Front thigh skinfold

Objective: To assess the thickness of the skin and underlying subcutaneous tissue at the midline of the anterior aspect of the thigh.

Method used: The subject assumed a seated position, leg extended with the torso erected. The front thigh skinfold was measured parallel to the long axis of the thigh at the marked site. The measurement was taken while the participant's leg was relaxed and resting on the anthropometric box. Where the front thigh skinfold was difficult to pick, the participants were asked to assist by lifting and supporting the hamstring to reduce tension of the skin.

Trials: Two measurements were taken and the average was recorded as the final score.

13. Medial calf

Objective: To assess the medial calf skinfold measured as a double fold of the skin and underlying subcutaneous tissue on the inside of the calf at the point of maximum girth.

Method used: The subject assumed a standing position, the right foot was placed on the box with the calf muscle relaxed. The medial calf skinfold measurement was taken vertically at the medial calf skinfold site. The skinfold is parallel to the long axis of the leg on the most medial point of the calf with a maximal circumference.

Trials: Two measurements were taken and the average was recorded as the final score.

J. Girths

Five girth measurements were taken using an anthropometric tape (Cescorf®-Brazil). The cross-hand measuring technique (Marfell-Jones *et al.*, 2006) was used for all girth measurements as recommended by the International Society for the Advancement of Kinanthropometry. When measuring girths, the anthropometric tape was held at a right angle to the body segment which was being measured. To achieve accuracy, the tension of the tape was monitored by ensuring that there were no indentations of the skin and by making sure that the tape was accurately place on the position. The girths that were measured included: arm relaxed, arm flexed and tensed waist, gluteal (hip) and calf. In all cases, a Cescorf® anthropometric tape was used for the girth measurements.

1. Arm relaxed girth

Objective: To determine the circumference of the arm at the level of mid-acromiale-radiale when the arm is relaxed.

Method used: The subject assumed a standing position with arms relaxed and hanging on the sides of the body. The right arm was slightly abducted to allow the measurement tape to pass around the arm.

Trials: Two measurements were taken and the average was recorded as the final score.

2. Arm flexed and tensed girth

Objective: To determine the circumference of the arm at the level of mid-acromiale-radiale when the biceps brachii is contracted and tensed.

Method used: The subject assumed a standing position in a relaxed stance with the left arm hanging by the side. The subject raised the right arm anteriorly to the horizontal with the forearm supinated 45^0 – $90^{0.}$ The measurer stood on the right side of the subject with the tape in position around the biceps. The subject was then asked to tense the elbow flexors in order to locate the peak of the contracted muscles. The subject then contracted the muscle fully and maintained that position until the reading was taken at the peak point of the contracted biceps brachii, which is normally at the mid acromiale-radiale landmark.

Trials: Two measurements were taken and the average was recorded as the final score.

3. Waist girth

Objective: To determine the circumference of the waist at the narrowest point between the lower costal border and the top of the iliac crest at right angle to the trunk.

Method used: The subject assumed a standing and relaxed position with the arms folded across the chest to allow the tape to pass around the abdomen freely. The measurer stood in front of the subject and placed the tape around the waist. The stub and the housing of the tape were held in one hand while the other hand adjusted the tape into the correct waist position.

The subject breathed normally and the measurement was taken at the end of the normal tidal expiration.

Trials: Three measurements were taken and the average was recorded as the final score.

4. Gluteal (hip) girth

Objective: To determine the total circumference of the hip around the buttocks at the point of highest protrusion at right angle to the trunk.

Method used: The subject stood feet together with gluteal muscles relaxed, and arms folded across the chest. The measurer placed the tape around the buttocks. The stub and the housing of the tape were held in one hand while the other hand adjusted the tape to the point of greatest protuberance and takes the reading.

Trials: Two measurements were taken and the average was recorded as the final score.

5. Calf girth

Objective: To determine the total circumference of the leg at the medial calf skinfold site at the point of maximum girth of the calf muscles.

Method used: The subject stood in an elevated position, arms hanging on the sides, feet shoulder-width apart and weight evenly distributed. The measurer used the cross hand technique. The stub and the housing of the tape were held in one hand while the other hand was used to adjust the tape to the correct position. The tape was set in a perpendicular plane to the axis of the leg without indenting the skin and the reading was taken.

Trials: Two measurements were taken and the average was recorded as the final score.

K. Bone breadths

Two breadths, namely the biepicondylar humerus and the biepicondylar femur were measured using a small Cescorf® bone calliper (Cescorf-Brazil). When taking the breaths measurements, the body of the calliper lay on the back of the hands and the thumb rested against the inner edge of the calliper branches, while the index finger was extended along the outside edge of the calliper branches. In this position the middle fingers are free to palpate the bony landmark where the calliper is to be placed. The index fingers were used to exert pressure to reduce the thickness of any underlying tissue (Marfell-Jones *et al.*, 2006).

1. Biepicondylar humerus

Objective: To determine the linear distance between the humeral epicondyles measured between the lateral humeral and the most medial humeral epicondyles.

Method used: The subject assumed a standing position with the right arm raised anteriorly and the forearm flexed at 90^0 angles to the arm. The measurer used the index fingers to palpate the epicondles of the humerus starting from the proximal to the site. The bony points that are first felt are the epicondyles. The measurer then placed the calliper faces on the epicondyles and maintained pressure through the index fingers until the reading was noted.

Trials: Two measurements were taken and the average was recorded as the final score.

2. Biepicondylar femur

Objective: To determine the linear distance between the femoral epicondyles measured between the lateral femoral and the most medial femoral epicondyles.

Method used: The subject assumed a seated and relaxed position with hands away from the knee region. The breadth was measured between the medial and lateral epicondyles of the femur. The middle fingers were used to palpate the epicondyles starting proximal to the site.

The calliper faces were placed on the epicondyles and the measurer then maintained pressure with the index fingers and recorded the values.

Trials: Two measurements were taken and the average was recorded as the final score.

The following body composition variables were computed:

a. Body mass index (BMI): BMI = BM/height^2

b. Fat mass: body weight (kg) × percentage body fat/100.

c. Fat-free mass: body weight (kg) - fat mass (kg).

d. Fat mass index: fat mass/height^2

e. Fat-free mass index: FFM/height$^{2.}$

Body Density (BD) was computed using the equation of Withers *et al* (1987) and the percentage body fat (%BF) was computed from body density using the Brozek and Keys (1963) equation.

1. Body Density = 1.0988 – 0.0004 (X^i).

2. %BF = (4.570/Bd – 4.142) x 100.

Where X^i = Σ7 skf (triceps,biceps, abdominal, supraspinale, subscapular, front thigh and medial calf in mm).

3. Endomorphy

$-0.7182 + 0.1451\ (\Sigma SKF \times Z) – 0.00068\ (\Sigma SKF \times Z)^{2} + 0.0000014 \times (\Sigma SKF \times Z)^{3}$

Where ΣSKF = sum of triceps, subscapular and supraspinale skf.

Z= 170.18/stature (in cm).

4. Mesomorphy

0.858 x (HM) + 0.601(FM) + 0.188 (CAG) + 0.161(CCG) – (S x 0.131) + 4.5

Where:

HM = humerus

FM = femur

CAG = corrected upper arm girth = upper arm girth- triceps skf/10

CCG = corrected calf girth = calf girth – calf skf/10

5. Ectomorphy

Ectomorphy was calculated using the height:weight ratio (HWR) on the following conditions:

If HWR is ≥ 40.75: Ectomorphy = 0.732 x HWR-28.58

If HWR is ≤ 40.75 but greater than 38.25: Ectomorphy = 0.463 x HWR – 17.63

If HWR = or less than 38.25: Ectomorphy = 0.1

L. Physical performance measurements.

All physical fitness tests were done in a stand football pitch, except for sitting and reach, vertical jump and shoulder flexibility which were done in the club gymnasia. A 5 minutes warm up session was done prior to performance of physical tests.

1. Flexibility test

(i) Sit and reach

Purpose of test: The purpose of the sit and reach test was to measure flexibility of the lower back and the hamstring muscles. These muscles are particularly active during soccer play. The test has a reliability of 0.89 (Jackson and Langford, 1986).

Equipment used: standard sit and reach box with a sliding ruler.

Test Procedure: The player assumed a sitting position, barefooted, with legs extended and feet placed against the box with a sliding ruler on the measuring chart. The subject extended arms and hands, with middle fingers aligned on top of each other. Knees were kept locked in a straight position as the arms reach as far forward as possible. The subject held the position for at least 3 seconds and a reading was taken for the distance moved by the fingers along the measuring chart.

Trials: The best reading from two trials was taken as the final score.

(ii) Shoulder flexibility test

Purpose of test: The purpose of the shoulder flexibility test was to measure the flexibility and mobility of the shoulder joint. Adequate range of motion in the shoulder is important for injury prevention and sporting performance in soccer and other sport which require throwing or catching skills.

Equipment used: flexible tape

Test Procedure: The subject assumed a standing position, with feet shoulder width apart. The right arm was raised straight up overhead for testing the left shoulder flexibility. The subject then bent the right elbow and let the right palm slide at the back of the neck and down the back between the shoulder blades to meet the left palm. The right hand moved down while the left moved up such that the fingers overlap. The distance between the fingertips of the right and left hand was recorded as the test score to the nearest centimeter. The subject then switched hands and performed the test on the opposite shoulder.

Trials: The best score from two trials was taken as the final score.

2. Leg Power

(i) Vertical jump

Purpose of test: The vertical jump test assessed the power of the leg muscles by calculating the vertical distance that the subject can jump. This test has a reliability of r = 0.92 (Fleishman, 1964).

Equipment used: Chalk powder, ruler with increments of one centimetre.

Test procedure: The subject stood with the strong side shoulder facing the board and pushed the ruler with the fingertip to set his reaching height without lifting the heels from the ground; this height was recorded. The fingertip of the stronger hand was then chalked. The subject took off from two feet and jumped straight upward, as high as possible and made a mark on the board with the chalked fingertip. Players were allowed to gather momentum by flexing the knees and swinging the arms. The height reached was recorded as the jump height and the difference between the reaching height and the jump height was noted as the player's vertical jump.

Trials: The best score from two trials was taken as the final score.

(ii) Standing/horizontal long jump

Purpose of test: The aim of the horizontal long jump was to measure the explosive power of the legs in a horizontal direction. This is an important test in soccer since most of the explosive movements in soccer take place in a horizontal direction.

Equipment used: Tape measure, an even non-slippery surface.

Test procedure: The subject stood feet parallel to each other on a starting line. He took off from double feet and jumped as far as possible landing on both feet. The player was allowed to gather momentum by flexing the knees, ankle and hips as well as from arm swinging. The distance from the starting line to the landing point was recorded. In the event that the subject fell back on landing, the distance from the starting line to the point where the last limb landed was recorded as the total distance covered. The measurements were recorded to the nearest centimeter.

Trials: The best score from two trials was taken as the final score.

3. Upper body power

(i) Overhead Power throw test

Purpose of Test: The purpose of the overhead power throw is to measures upper body strength and explosive power of the arms.

Equipment used: 2 kg medicine ball, tape measure and an even surface.

Test procedure: The player stood on the starting line with feet shoulder width apart, facing forward. The subject held the ball with two hands slightly behind the center. The throwing action is similar to that used for a soccer throw-in. The subject brought the ball backwards behind the head, and threw it with maximum power forward as far as possible. The players were allowed to step forward over the line after the ball was released. The maximum distance thrown was recorded to the nearest 10 cm.

Trials: The best throw from two trials was taken as the final score.

4. Agility test

(i) Illinois test

Agility is an important component of many team sports, which involve rapid changes of direction and speed of play. It is a vital component in the game of soccer which involves quick short runs with the ball, combined with dribbling and turning in various unanticipated directions. The length of the course was 10 meters and the width (distance between the start and finish points) was 5 meters. Four cones were used to mark the start, finish and the two turning points. Another four cones were placed down the center an equal distance apart. Each of the center cones was spaced 3.3 meters apart (Fig 5.1).

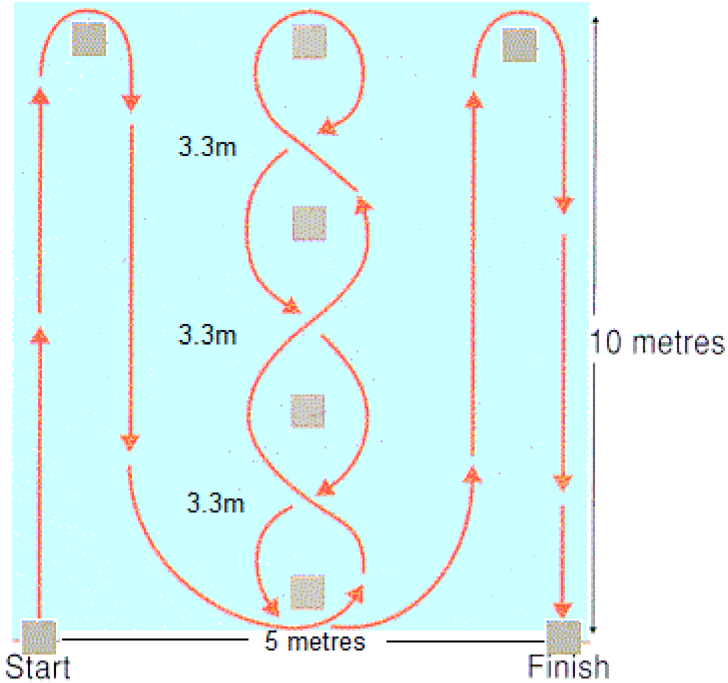


Fig 5.1. Illinois test course *(Adapted from Semenick, 1979)*

Purpose of test: To measure the ability of players to run fast and rapidly change the direction of the body by combining speed, coordination and balance.

Equipment used: Flat non-slip surface, cones, timing gates, whistle and measuring tape.

Procedure: Players assumed a prone position a meter behind the timing gates and hands by their shoulders. On the 'Go' command the player got up as quickly as possible and ran around the course in the direction indicated, without knocking the cones over, to the finish line, at which the time taken to complete the course was recorded on the timing gate.

Trials: The best time score from two trials was taken as the final score.

5. Sprint speed

(i) 10, 20 and 40 meter sprints

Purpose of test: To assess the speed abilities and acceleration of the players over distances of 10 meters, 20 meters and 40 meters.

Equipment used: 50m tape measure, 8 cones, whistles, timing gates (Cadex®-Canada), level grass surface.

Procedure: For each of the three tests, the subjects covered the required distance from a static position in the shortest possible time. From a 'go' command the subject started running from a stationary position. Two cones were placed a meter before the first timing gate to mark the starting point and another one 1 meter after the last timing gate. The timing gates were adjusted accordingly for 10m, 20m and 40m and maximum encouragement was given to them so that they run up to the last timing gate.

Trials: The fastest time from two attempts was recorded as the individual's score.

6. Aerobic fitness

(i) Single soccer-specific fitness test (Hoff's test)

Purpose of test: The Hoff's test was used to indirectly measure the VO_{2max} of the players, as well as to assess soccer-specific skills such as running with the ball, ball controlling, dribbling, passing and shooting over a distance of 290 meters within the shortest possible time.

Equipment: 22 cones, whistle, hurdles and an even grass surface.

Procedure: The players started from a 'Go' command and performed the circuit of activities including sprinting with the ball for 12m and dribbling around 10 cones placed 2m apart. They then proceeded to clear 3 hurdles, 7m apart passing the ball underneath the hurdles (30-35cm high), then changed direction and sprinted for 30.5m. The players then ran with the ball around 6 cones placed 25m apart in a zigzag way back to the starting point (Fig 5.2).

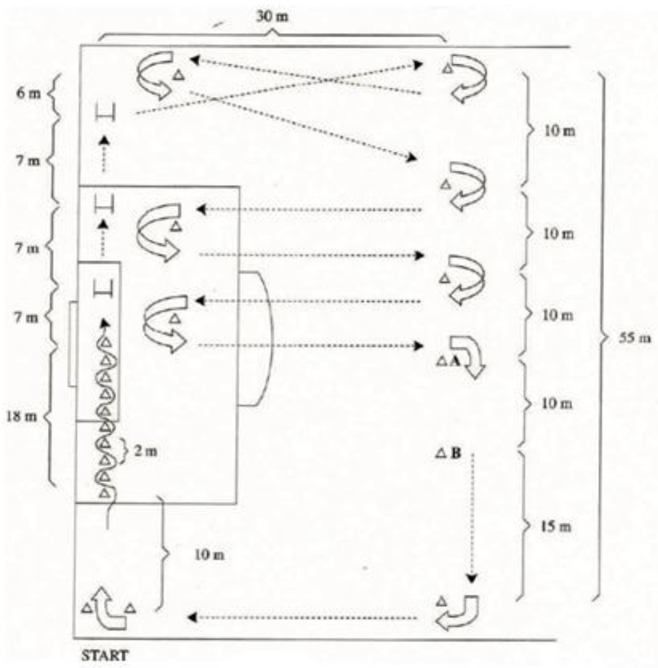


Fig 5.2 Hoff's dribbling track (*Adapted from Hoff et al., 2002***)**

At the lapse of 10 minutes the player was stopped and the distance covered was calculated. This distance was used to determine the player's VO_{2max}.according to the Hoff's VO_{2max} normative table four players were tested at a given time. After the first player started, one minute was allowed for the next player to start. Time left for each player was announced at 5 minute and at 9 minutes. For easy identification of players, each player wore a different colored bib.

Trials: Players only completed one trial.

M. Maturity index

Maturity offset was calculated according to the equation of Mirwald *et al*. (2002), which incorporates chronological age of players, height, body mass, sitting height and leg length, where leg length was calculated as total height minus sitting height. The method has been shown to estimate maturity status with an error of ±1.18 years in boys and ±1.14 years in girls (Mirwald *et al*., 2002).

Offset = -29.769 + 0.0003007(Leg Length and Sitting Height interaction)-0.01177(Age and Leg Length interaction) +0.01639(Age and Sitting Height interaction) +0.445(Leg by Height ratio.)

N. Data analysis

Results were reported as mean scores and standard deviations using software packages, Statistical Package in Social Sciences (SPSS version 16) and (SOAMTOTYPE V. 1_2_5). Descriptive and comparative statistics were used to describe and determine the differences between body composition and functional ability of South African and Zimbabwean young soccer players. Data was presented in the form of tables and graphs and was done in relation to the study objectives. All variables were described and compared according to playing positions for each country and then compared according to playing positions for the two countries combined. Student's T-tests were used to compare means between South African and Zimbabwean players. One-Way Analysis of Variance (ANOVA) was used to determine the differences between playing positions, while differences in somatotype between teams and among playing positions were computed using Somatotype Analysis of variance (SANOVA). A p-value of 0.05 was considered statistically significant.

CHAPTER 6

RESULTS

A. Introduction

A total of 40 Zimbabwean were approached by the researcher to request for consent to participate in the study as research subjects to which they all agreed. Of the 40 who agreed to participate, 7 players (17.5%) did not turn up and 33 subjects (82.5%) were tested. On the South African team, 49 players were approached and they all gave consent. 8 players (12.8 %) did not turn up for testing and 41 subjects (87.2%) were tested. All together 89 players gave their consent to participate in the study and 74 (83.1%) took part in the study.

Table 6.1. Distribution of the study sample according to position of play

Playing position	Zimbabwe	South Africa	Total
Goalkeepers	5	5	10
Defenders	7	14	21
Midfielders	11	12	23
Forwards	10	10	20
Total	33	41	74

Except for defenders, all the playing positions had almost an equal number of subjects tested from Zimbabwe and South Africa. More defenders (14) were tested from South Africa compared to Zimbabwe (7) (Table 6.1).

B. Body composition and somatotype characteristics

1. Anthropometry

a. Anthropometry for directly measured body composition variables

Fig 6.1 shows that the age range of the players varied between 14.5 and 17.8 years. In table 6.2, there were no statistically significant differences in age or standing height between the two groups (p = 0.79 and p = 0.61, respectively). However, the Zimbabwean players were statistically significantly heavier (p = <0.05) compared to the South Africans.

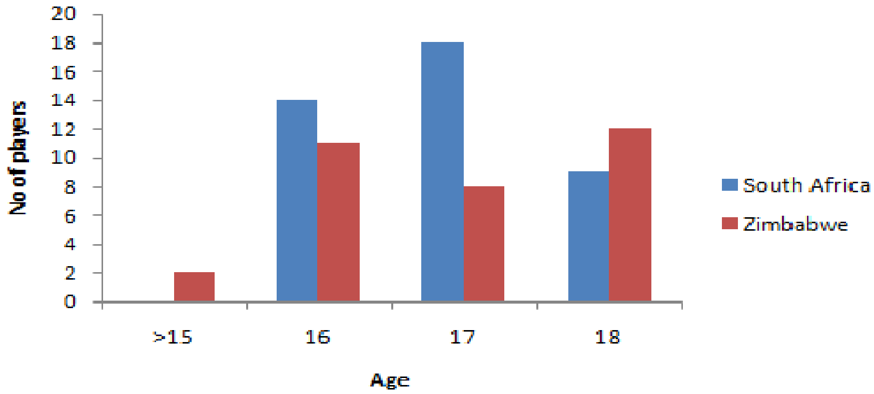


Figure 6.1. Age distribution of participants

Table 6.2. Comparative anthropometry statistics of South African (n = 41) and Zimbabwean (n = 33) players (directly measured body composition variables) (values are mean ± SD)

Characteristics	Total	South Africa	Zimbabwe	P-value
Age (years)	15.9±0.81	15.9±0.70	16±0.93	> 0.05
Body Mass (kg)	59.9±8.47	58.3±10.26	61.9±4.95	>0.05
Height (cm)	169.7±5.89	169.4±6.54	170.1±5.05	> 0.05
Sum of 8 skinfolds (mm)	55.0±18.48	61.4±22.11	47.1±7.18	0.01

There was no statistically significant difference between the height and weight of the South African and the Zimbabwean teams. Figure 6.2a shows that the South African team had one player with exceptionally lower height than the rest of the group and three other outliers on body mass, while the Zimbabwean team had one player who was noted to have outstandingly high body mass than the rest of the team. The South African players had statistically significantly greater sum of skinfolds than the Zimbabwean players (p = 0.01), mainly due to the effect of the three outliers on the mean value as indicated in Figure 6.2(c).

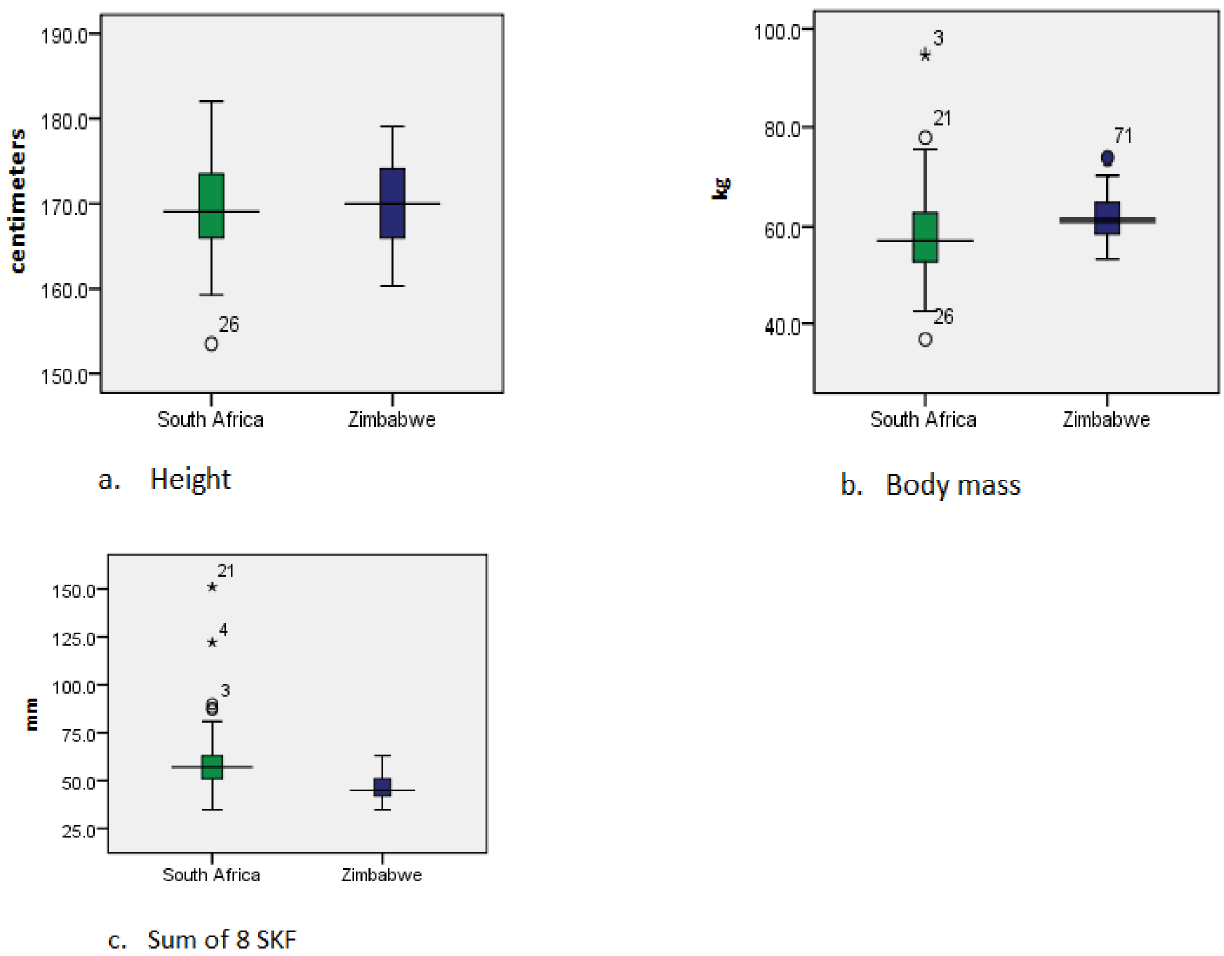


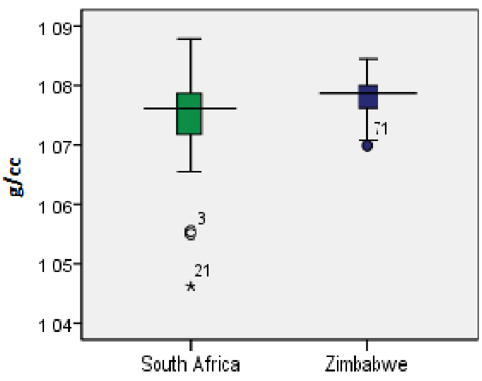
Figure 6.2. Comparisons of directly measured body composition variables between South African and Zimbabwean players

b. Anthropometry for derived body composition variables

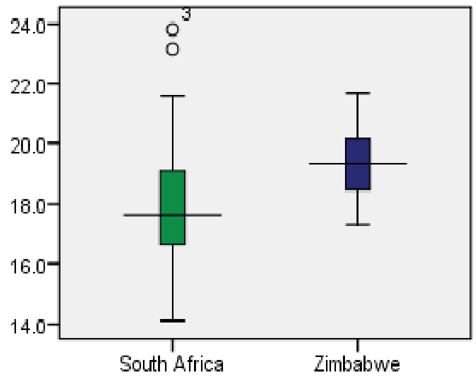
According to Figure 6.3(a), the South African players had statistically significantly higher values of percentage body fat (p = 0.03) and had two outliers with outstanding %BF, fat mass, body density, fat free mass index and three in fat free mass values while Zimbabwe had one outlier with outstanding %BF and another one in body density value (Figure 6.3(b-e). The South African team had significantly high value of fat mass (Table 6.3), while the Zimbabwean players were significantly leaner and more muscular with one outlier (Figure 6.3(b). Figure 6.3(d) shows that two South African players had exceptionally less body density than Zimbabwean players due to the effect of higher fat mass (Table 6.3). However, the Zimbabwean players had high values in BMI and WHR. (Table 6.3)

Table 6.3. Comparative anthropometry statistics of South African (n = 41) and Zimbabwean (n = 33) players (derived body composition variables) (values are mean ± SD)

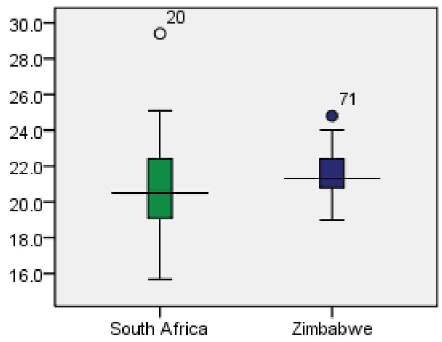
Characteristics	Total	South Africa	Zimbabwe	P-value
Percentage body fat (%)	9.9±2.97	10.5±3.61	9.0±1.6	0.03
Fat mass (kg)	6.0±2.68	6.4±3.40	5.6±1.28	> 0.05
Fat free mass (kg)	53.9±6.7	51.9±7.69	56.3±4.17	0.00
Fat mass index	2.0±0.87	2.2±1.10	1.95±0.43	> 0.05
Fat free mass index	1.8±1.90	1.8±2.14	1.9±1.19	0.00
Body density (g/cc)	1.07±0.00	1.07±0.00	1.08±0.00	0.03
Body mass index (kg/m2)	20.9±2.12	20.5±2.51	21.4±1.39	0.08
Waist-hip ratio	0.82±0.06	0.81±0.07	0.84±0.03	0.02



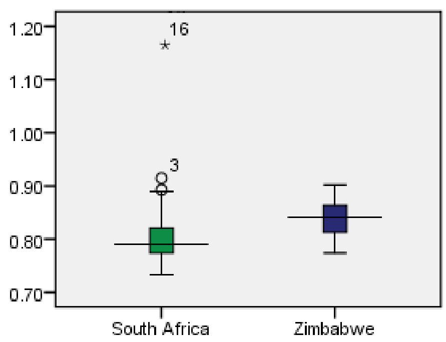
d. Body density



e. Fat free mass index



f. BMI



g. WHR

Figure 6.3. Comparative derived body composition variables (a-e) for the South African and Zimbabwean players

c. Anthropometry: South Africa and Zimbabwe according to position of play

In Table 6.4 an analysis of the body composition of all players by playing positions indicated that goalkeepers were the tallest and heaviest. They also showed a higher %BF and BMI. Forwards, on the other hand, presented the lowest on all variables except BMI (Table 6.4). No significant differences between players in different playing positions were observed for any of the body composition variables, although body mass approached statistical significance ($p = 0.05$).

Table 6.4. Anthropometric characteristics of South African and Zimbabwean (combined) players according to playing positions (values are mean ± SD)

Characteristics	Goalkeepers (n=10)	Defenders (n=21)	Midfielders (n=23)	Forwards (n=20)	P-value
Age (years)	15.8±1.03	15.8±0.79	16.1±0.81	16.0±0.72	> 0.05
Height (cm)	172.0±5.74	171.1±5.37	169.9±6.70	166.88±4.58	>0.05
Body mass (kg m^2)	65.6±6.01	59.6±10.4	59.9±7.71	57.40±7.10	= 0.05
Sum of 8 skinfolds (mm)	63.1±33.6	55.4±21.3	56.2±11.7	49.5±8.3	> 0.05
Body density (g/cc)	1.07±0.10	1.07±0.00	1.07±0.00	1.07±0.00	> 0.05
Percentage body fat (%)	11.1±4.55	9.7±3.64	10.2±1.85	9.02±2.06	> 0.05
Body mass index	21.4±1.91	20.7±2.77	20.9±1.87	20.9±1.81	> 0.05

d. Anthropometry: South Africa according to positions of play

No significant difference in age was observed among the South African players across playing positions (p>0.05). Goalkeepers and defenders were of similar age, while midfielders and forwards were slightly younger (Table 6.5). Goalkeepers were the heaviest of all the other groups, while defenders were the tallest and forwards were the lightest and shortest. A statistically significant difference was observed in height of the players across playing positions (p = 0.05), with a greater difference existing between forwards and defenders. No significant differences were seen in all other variables across playing positions.

Table 6.5. Anthropometric scores for South African players according to playing positions (values are mean ± SD)

Characteristics	Goalkeepers (n=5)	Defenders (n=14	Midfielders (n=12	Forwards (n=10	P-value
Age (years)	16.0±.070	16.0±0.67	15.9±0.79	15.9±0.73	> 0.05
Height (cm)	169.5±5.95	172.4±5.90	169.7±7.27	164.9±4.90	= 0.05
Body mass (kg)	66.7±7.26	59.1±12.5	57.5±9.14	53.8±7.1	> 0.05
Sum of 8 skinfolds (mm)	79.8±42.68	62.1±23.20	63.2±10.46	49.4±9.94	<0.05
Body density	1.06±0.013	1.07±0.009	1.07±0.004	1.07±0.005	> 0.05
Percentage body fat	13.0± 6.09	10.7± 4.07	11.0± 1.74	8.6± 2.40	> 0.05
Body mass index	21.4± 2.81	20.4± 3.34	20.4± 1.85	20.5± 1.97	> 0.05
Waist-hip ratio	0.8±0.04	0.8±0.04	0.8±0.11	0.8±0.03	> 0.05

e. Anthropometry: Zimbabwe according to positions of play

There was no significant difference across playing positions for any anthropometric variables ($p > 0.05$). Goalkeepers were the tallest and heaviest compared to other players, while defenders and forwards were the shortest and lightest in the group. Goalkeepers, midfielders and forwards had the highest %BF, while defenders had the lowest (Table 6.6).

Table 6.6. Anthropometric scores for Zimbabweans according to playing positions (values are mean ± SD)

Characteristics	Goalkeepers (n=5)	Defenders (n=7)	Midfielders (n=11)	Forwards (n=10)	P - value
Age (years)	15.6±1.34	15.5±0.97	16.3±0.80	16.1±0.73	>0.05
Height (cm)	174.6±4.79	168.8±3.32	170.1±6.46	168.7±3.51	> 0.05
Body mass (kg)	64.5±5.03	60.6±4.54	62.5±4.94	60.9±5.31	> 0.05
Sum of 8 skinfolds (mm)	46.4±5.22	42.1±6.28	48.5±7.94	49.5±6.85	> 0.05
Body density	1.07±0.001	1.08±0.003	1.07±0.039	1.07±0.003	> 0.05
Percentage body fat	9.3±0.78	7.9 ±1.45	9.4±1.69	9.4±1.70	> 0.05
Body mass index	21.5±0.58	21.2±0.97	21.5±1.77	21.4±1.61)	> 0.05
Waist-hip ratio	0.79±0.04	0.80±0.04	0.79±0.04	0.81±0.79	> 0.05

2. Somatotype analysis

a. Somatotype: South Africa and Zimbabwe

South African players were mesomorphic ectomorphs (bigger and muscular), while Zimbabweans were ectomorphic mesomorph (lean and muscular). According to figure 6.4 the South African team had three players who were mesomorphic endomorphs and two who were endomorphic ectomorphs. There were statistically significant differences in all somatotype categories between South African and Zimbabwean players ($p < 0.01$).

Table 6.7. Comparative somatotype statistics of South African (n = 41) and Zimbabwean (n = 33) players (values are mean ± SD)

Team	N	Mean	SD	P
South Africa	41	2.03 - 3.28 - 3.61	0.92 - 1.52 - 1.46	P = 0.00
Zimbabwe	33	1.61 - 4.38 - 2.91	0.33 - 1.04 - 0.82	

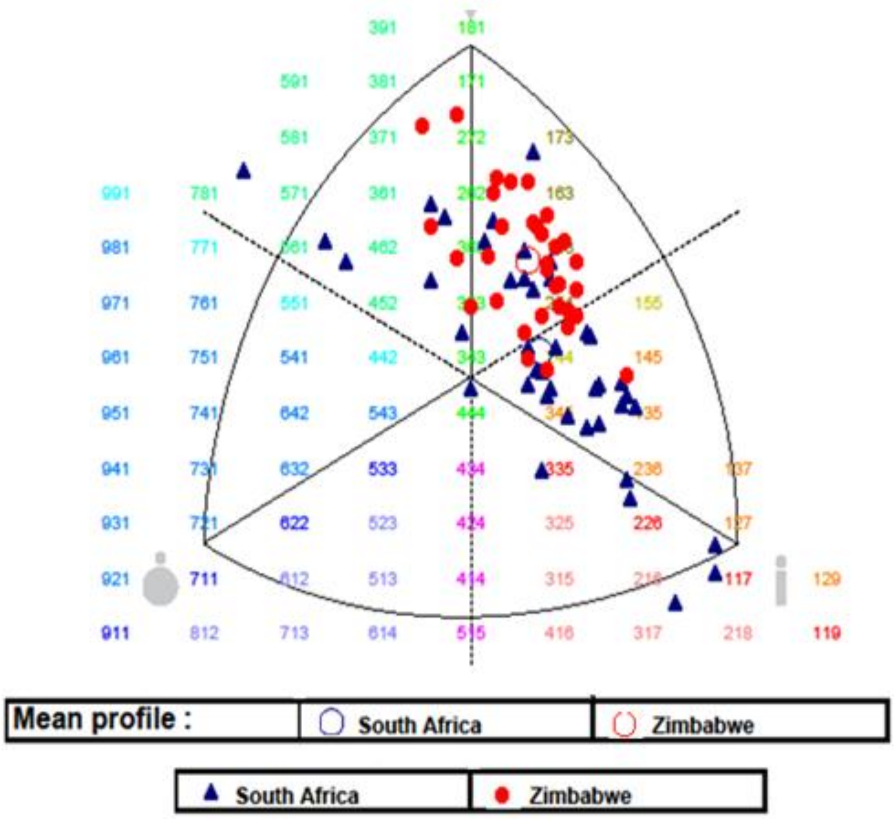


Figure 6.4. Comparative somatoplots of South African and Zimbabwean players

b. Somatotype: South Africa and Zimbabwe according to positions of play

Figure 6.5. shows that forwards and midfielders were lean and muscular (mesomorph ectomorph), defenders were lean and muscular but taller (mesomorphic ectomorphs), while

goalkeepers were taller and muscular (balanced mesomorphs (Figure 6.5). There were no statistically significant somatotype differences noted when all players were analysed according to playing positions (p = 0.1). (Table 6.8)

Table 6.8. Comparative somatotype statistics of all players, goalkeepers (n = 10), defenders (n = 21), midfielders (n=23), forwards/strikers (n=20) (values are mean ± SD)

Position of play	N	Mean somatotype	SD	P
Goalkeepers	10	2.3 - 4.70 - 2.52	1.52 - 1.23 - 1.13	0.1
Defenders	21	1.93 - 3.27 - 3.75	0.82 - 1.66 - 1.47	
Midfielders	23	1.66 - 3.80 - 3.10	0.41 - 1.07 - 0.92	
Forwards	20	1.85 - 3.92 - 3.32	0.44 - 1.31 - 1.20	

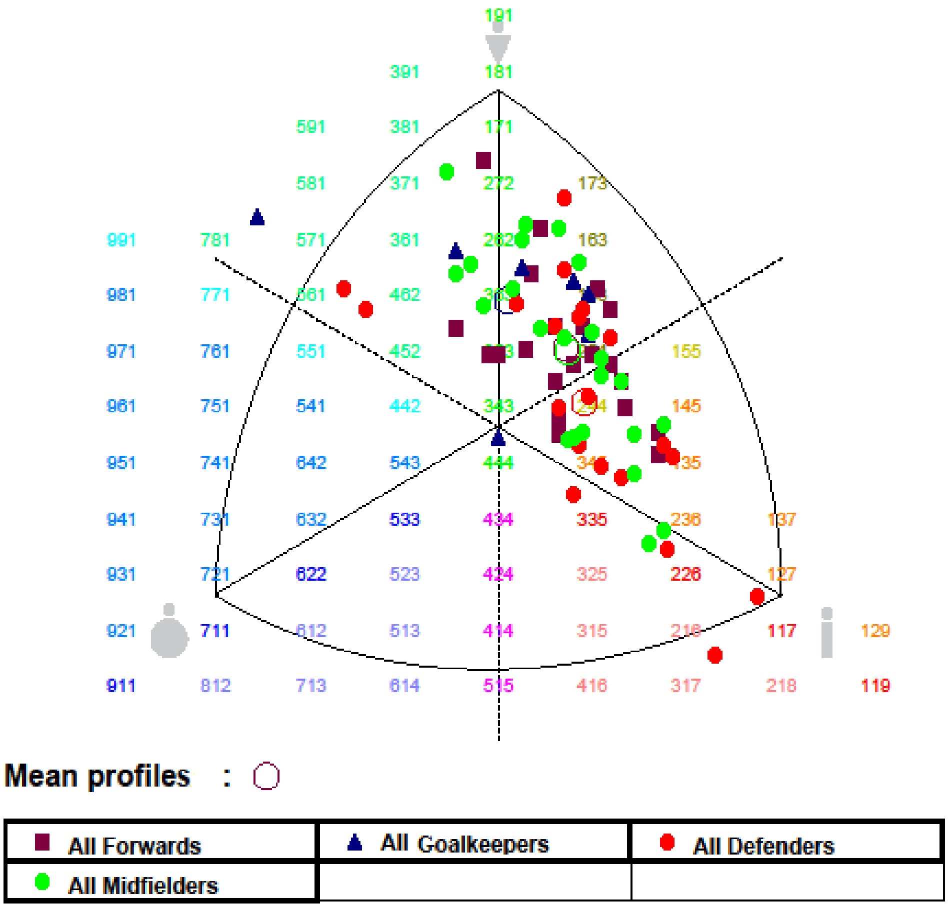


Figure 6.5. Comparative somatoplots of all positions of play: forwards; goalkeepers; midfielders and defenders

c. Somatotype: South African and Zimbabwean goalkeepers

There was no statistically significant difference ($p > 0.05$) in the somatotype of goalkeepers of the two teams (Table 6.9), but South African goalkeepers were bigger and taller while Zimbabweans were more muscular. The South African goalkeepers were endomorphic mesomorphs, mainly because of one goalkeeper who was fatter and taller (outlier). All Zimbabwean goalkeepers were ectomorphic mesomorphs (Figure 6.6). Of more interest was that there was a dominancy of the mesomorphic component in both teams.

Table 6.9. Comparative somatotype statistics of South African (n = 5) and Zimbabwean (n = 5) goalkeepers (values are mean ± SD)

Team	N	Mean	SD	p
South African	5	3.08 - 4.77 - 1.70	1.96 - 1.81 - 1.07	0.13
Zimbabwean	5	1.56 - 4.70 - 3.28	0.11 - 0.42 - 0.19	

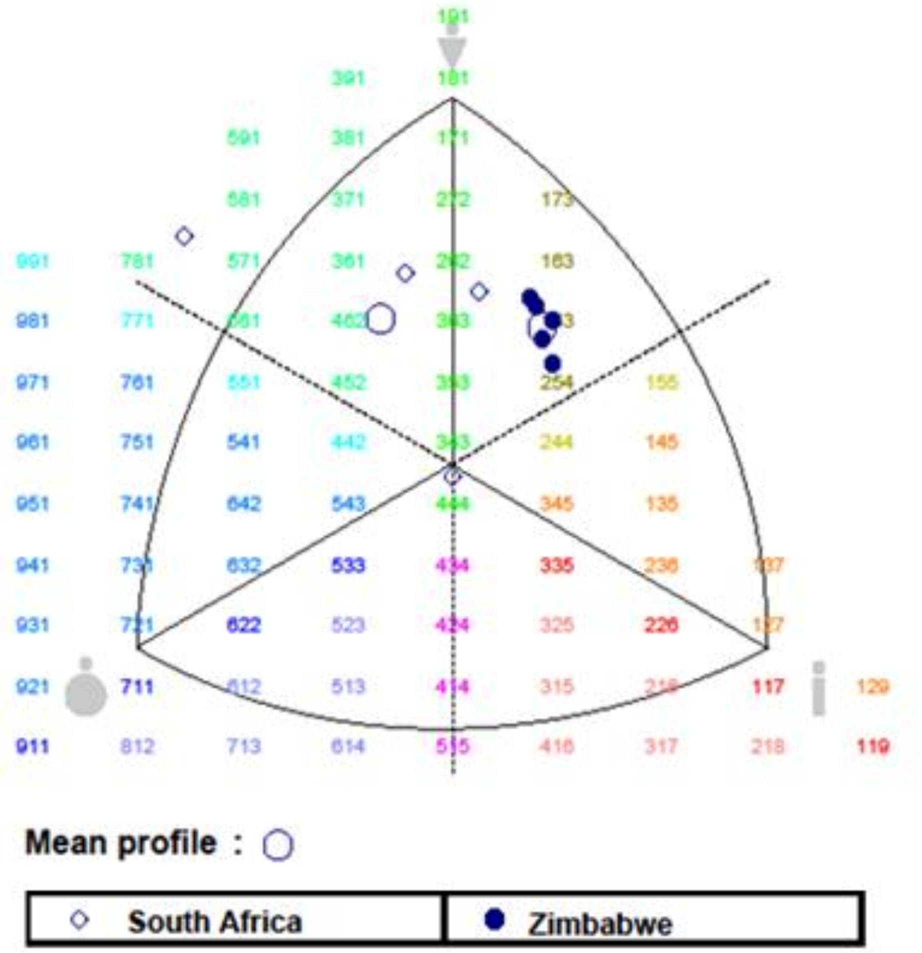


Figure 6.6. Comparative somatoplots of South African and Zimbabwean goalkeepers

d. Somatotype: South African and Zimbabwean defenders

From figure 6.7 South African defenders were more spread on the somatoplot and had different somatotype characteristics, whereas Zimbabweans were homogeneous. No significant differences were observed between South African and Zimbabwean defenders (p = 0.21) (Table 6.10). Players from both teams were predominantly mesomorphic ectomorphs, but Zimbabweans were lighter, leaner and more muscular compared to the South Africans.

Table 6.10. Comparative somatotype statistics of South African (n = 14) and Zimbabwean (n = 7) defenders (values are mean ± SD)

Team	N	Mean	SD	P
South Africa	14	2.07 - 3.03 - 4.02	0.91 - 1.80 - 1.59	0.21
Zimbabwe	7	1.45 - 3.70 - 2.93	0.28 - 1.12 - 0.47	

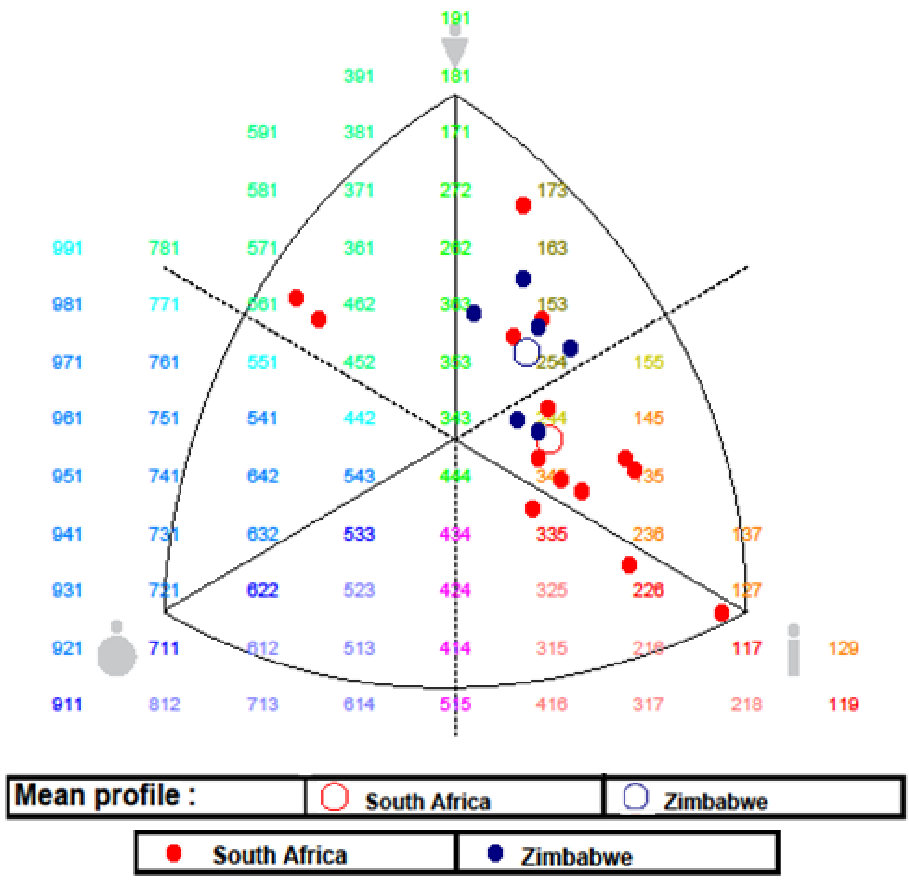


Figure 6.7. Comparative somatoplots of South African and Zimbabwean defenders

e. Somatotype: South African and Zimbabwean midfielders

There were statistically significant differences in the somatotype between the midfielders of the two teams (p = 0.01) (Table 6.11). Midfielders from both teams were equally spread on the somatoplot and were mesomorphic ectomorphs (Figure 6.8). The South African midfielders were tall and leaner, while the Zimbabweans were shorter and more muscular.

Table 6.11. Comparative somatotype statistics of South African (n = 12) and Zimbabwean (n = 11) midfielders (values are mean ± SD)

Team	N	Mean	SD	p
South Africa	12	2.02 - 3.27 - 3.85	0.42 - 1.21 - 1.04	0.01
Zimbabwe	11	1.67 - 4.64 - 2.74	0.41 - 1.03 - 1.12	

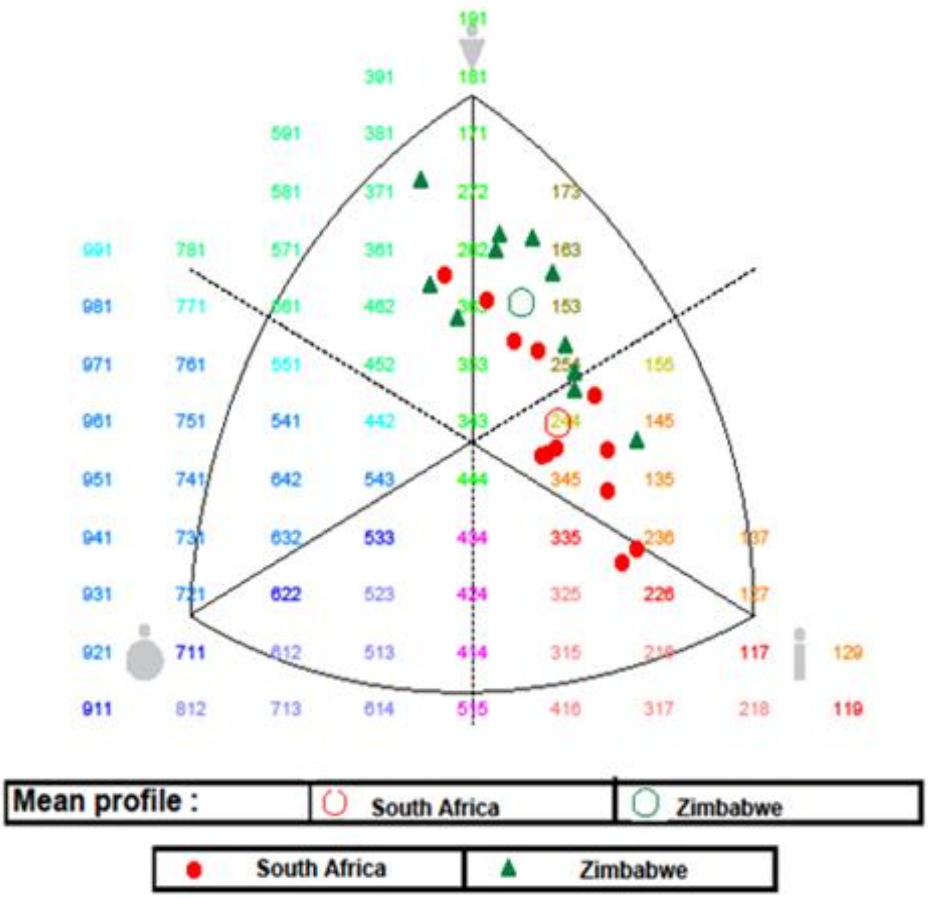


Figure 6.8. Comparative somatoplots of South African and Zimbabwean midfielders

f. Somatotype of South African and Zimbabwean forwards

There were no significant differences in somatotype of South African and Zimbabwean forwards ($p > 0.05$), however Zimbabwean forwards were more muscular compared to South

Africans. (Table 6.12). South Africans were mesomorph-ectomorphs, while Zimbabweans were ectomorphic mesomorph. Both teams had the mesomorphic and ectomorphic components (Figure 6.9).

Table 6.12. Comparative somatotype statistics of South African (n = 10) and Zimbabwean (n = 10) forwards (values are mean ± SD)

Team	N	Mean	SD	p
South Africa	10	1.65 - 3.20 - 3.31	0.51 - 0.61 - 1.02	> 0.05
Zimbabwe	10	1.66 - 4.34 - 2.90	0.33 - 1.14 - 0.81	

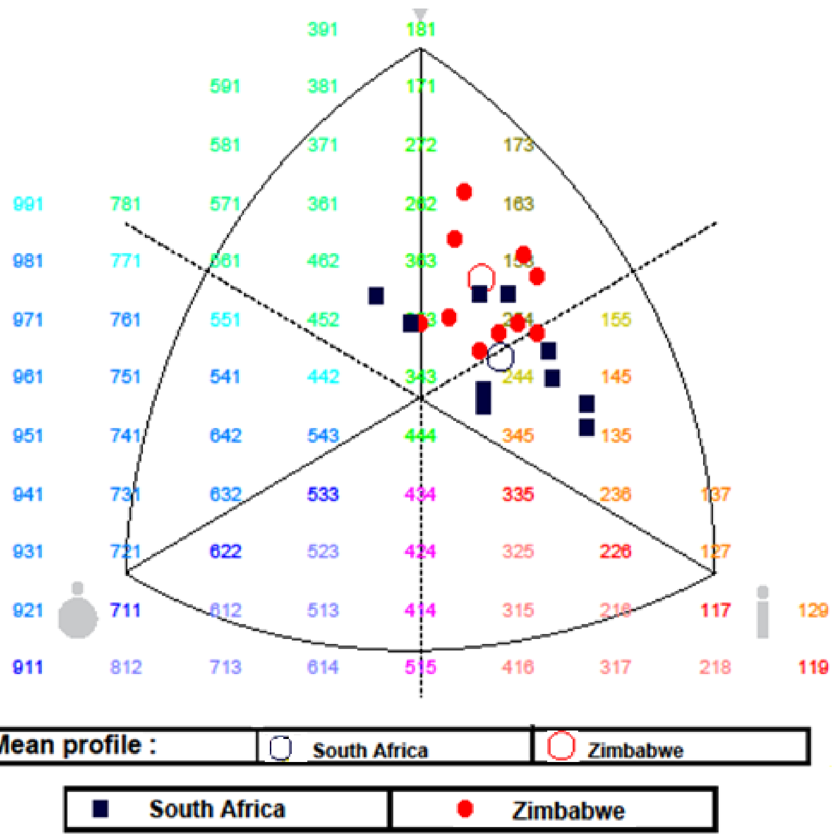


Figure 6.9. Comparative somatoplots of South African and Zimbabwean forwards

C. Functional fitness capacity

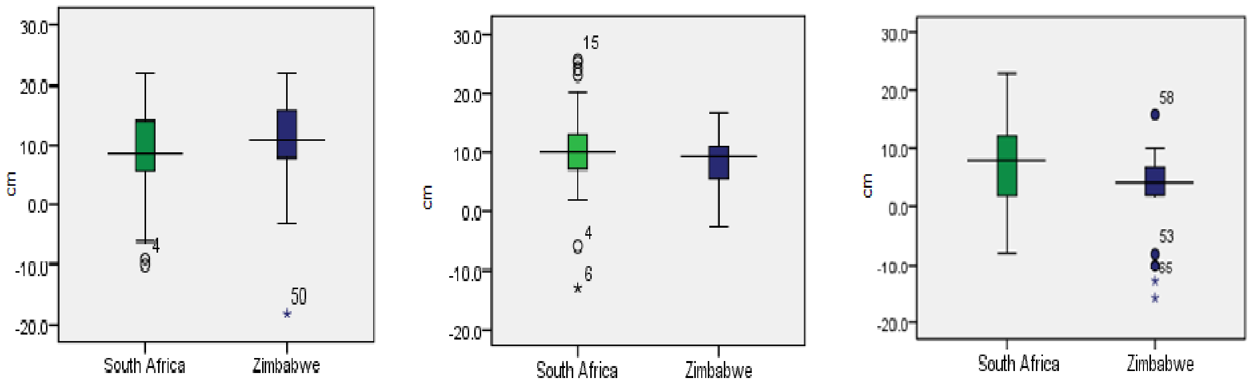
1. Flexibility

a. Flexibility for South Africa and Zimbabwe

Table 6.13 shows that the Zimbabwean players were more flexible than the South African players in the sit and reach tests. However, only the shoulder flexibility to the left resulted in statistically significantly better scores by the South African players (p = 0.01), while there were no statistically differences in sit and reach as well as right shoulder flexibility . Figure 6.10(a) also indicates that, in both groups there was one individual who demonstrated exceptional poor lower back/hamstring flexibility. Figure 6.10(a) shows that in both groups there were players who had negative sit and reach scores, meaning that their lower back muscles were extremely tight. According to Figure 6.10(b), there were three outliers in the South African team on right shoulder flexibility, two of them had negative scores and one had extremely high scores. In Figure 6.10(c) there are two Zimbabwean players with negative scores while one player had remarkably high scores in left shoulder flexibility.

Table 6.13. Flexibility scores for South African (n = 41) and Zimbabwean (n = 33) players (values are mean ± SD)

Test	Total	South Africa	Zimbabwe	P-value
Sit and Reach (cm)	9.6±7.75	9.2±7.20	10.1±8.47	> 0.05
Right shoulder flexibility (cm)	9.4±6.65	10.2±7.82	8.3±4.70	> 0.05
Left shoulder flexibility(cm)	4.7±7.49	6.6±7.26	2.4±7.24	= 0.01



a. Sit & reach b. Rightt shoulder flexibility c. Leftt t shoulder flexibility

Figure 6.10. Comparative flexibility of South African and Zimbabwean players

b. Flexibility: South Africa and Zimbabwe according to positions of play

From Table 6.14, the South African and Zimbabwean players (combined) showed statistically significant differences in sit and reach test according to playing positions ($p = 0.01$), while there was no significant difference in both right and left shoulder flexibility across playing positions. Figure 6.11 shows that goalkeepers had significantly better scores in all three flexibility tests compared to other players. Defenders had the lowest scores in the sit and reach test while forwards and midfielders had lowest scores in all shoulder flexibility tests. There were bigger differences between the sit and reach scores of defenders and goalkeepers; defenders and midfielders, as well as goalkeepers and forwards.

Table 6.14. Flexibility of South African and Zimbabwean players (combined) according to playing positions (values are mean ± SD)

Test	Goalkeepers (n=10)	Defenders (n=21)	Midfielders (n=23)	Forwards (n=20)	P- value
Sit and Reach	15.0±6.06	5.6±8.49	11.3±5.90	9.2±7.78	= 0.01
Right shoulder flexibility	10.4±2.74	10.0±7.95	9.5±6.61	8.0±6.80	> 0.05
Left shoulder flexibility	6.2±3.32	4.7±10.1	4.3±6.91	4.5±6.80	> 0.05

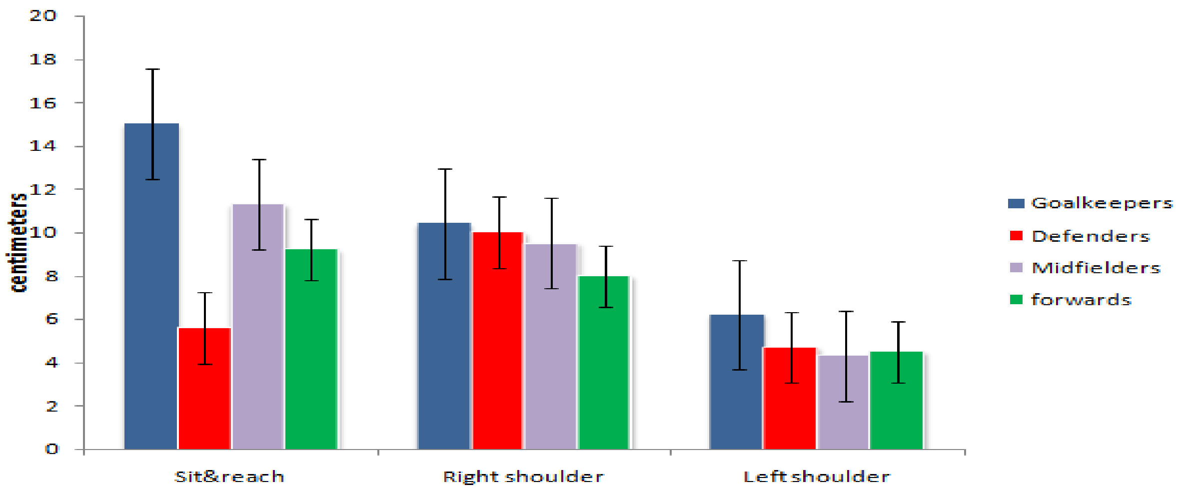


Figure 6.11. Flexibility of South African and Zimbabwean players all playing positions combined.

c. Flexibility: South Africans according to positions of play

Goalkeepers had the most flexible lower back muscles compared to other players, whereas defenders had the least flexible lower back muscles (Table 6.15). Defenders had higher scores for both right and left shoulder flexibility, whilst forwards and midfielders had the lowest scores in these tests. However, overall there were no statistically significant differences in flexibility of players in different playing positions ($p > 0.05$). (Table 6.15).

Table 6.15. Flexibility of South African players according to playing positions (values are mean ± SD)

Test	Goalkeepers (n=5)	Defenders (n=14)	Midfielders n=12)	Forwards (n=10)	P – value
Sit and Reach (cm)	14.2±4.51	6.4±6.11	9.7±7.06	10.1±8.89	>0.05
Right shoulder flexibility (cm)	10.6±3.22	11.9±8.63	10.3±8.01	7.7±8.34	> 0.05
Left shoulder flexibility (m)	7.0±4.26	8.1±9.30	4.6±7.78	6.6±4.38	> 0.05

d. Flexibility: Zimbabweans according to positions of play

Similarly to the South Africans, the Zimbabwean goalkeepers were the most flexible group in all the flexibility tests, followed by midfielders and forwards (Table 6.16). The Zimbabwean defenders had the lowest (and negative values) in sit and reach and left shoulder flexibility tests (Figure 6.12). There was a statistically significant difference ($p = 0.05$) in hamstring and lower back muscles flexibility across playing position, but no significant difference in shoulder flexibility ($p > 0.05$).

Table 6.16. Flexibility of Zimbabweans according to playing positions (values are mean ± SD)

Test	Goalkeepers n=5	Defenders (n=7)	Midfielders (n=11)	Forwards (n=10)	P – value
Sit and Reach	15.8±7.79	4.0±12.45	13.1±3.87	8.4±6.86)	= 0.05
Right shoulder flexibility	10.1±2.51	-6.2±4.86	8.7±4.91	8.4±5.27	> 0.05
Left shoulder flexibility	5.3±2.18	-1.9±8.66	4.0±6.17	2.4±8.28	> 0.05

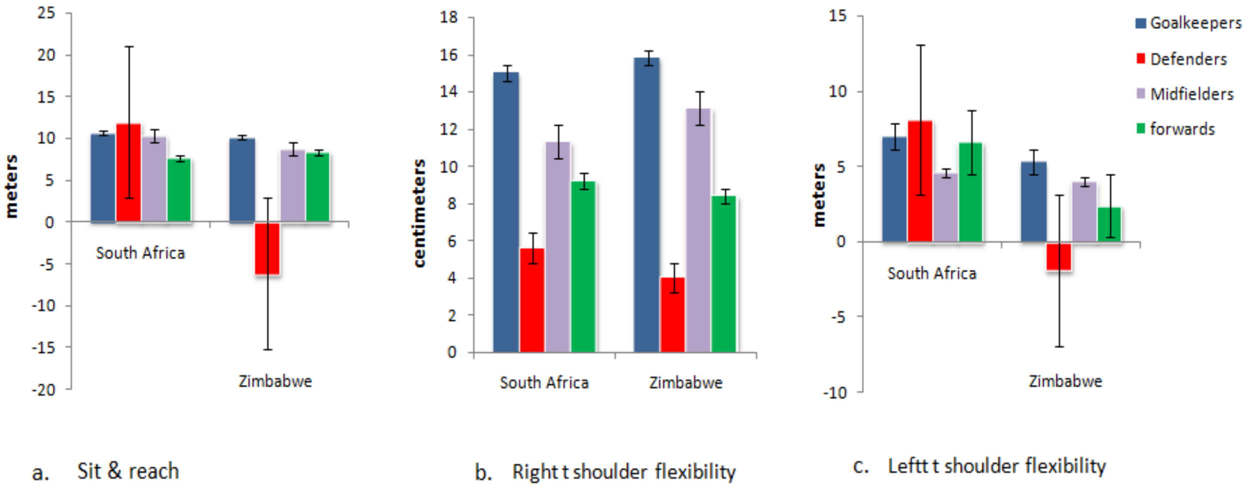


Figure 6.12. Comparative flexibility of South African and Zimbabwean players according to position of play

2. Upper and lower body power

a. Upper and lower body power for South Africa and Zimbabwe

The Zimbabwean players performed statistically significantly better in all three power tests compared to the South African players (Table 6.17). There was statistically significant difference between two team in vertical jump and horizontal jump (p=0.00) as well as in overhead throw (p = 0.01). There were two players in each team who performed exceptionally well (outliers) in the horizontal jump test compared to the rest of the players (Figure 6.13b). The Zimbabwean team had one individual at the upper and lower end of the range who can be considered outliers in comparison with the rest of the group in overhead throw test. (Figure 6.13b).

Table 6.17. Upper and lower body power of South African (n = 41) and Zimbabwean (n = 33) players (values are mean ± SD)

Test	Total	South Africa	Zimbabwe	P-value
Vertical jump (cm)	46.8±6.68	44.5±6.60	49.7±5.61	< 0.001
Horizontal jump (cm)	2.2±0.27	2.1±0.32	2.3±0.12	< 0.001
Overhead throw (cm)	9.0±1.26	8.7±1.39	9.4±0.95	= 0.01

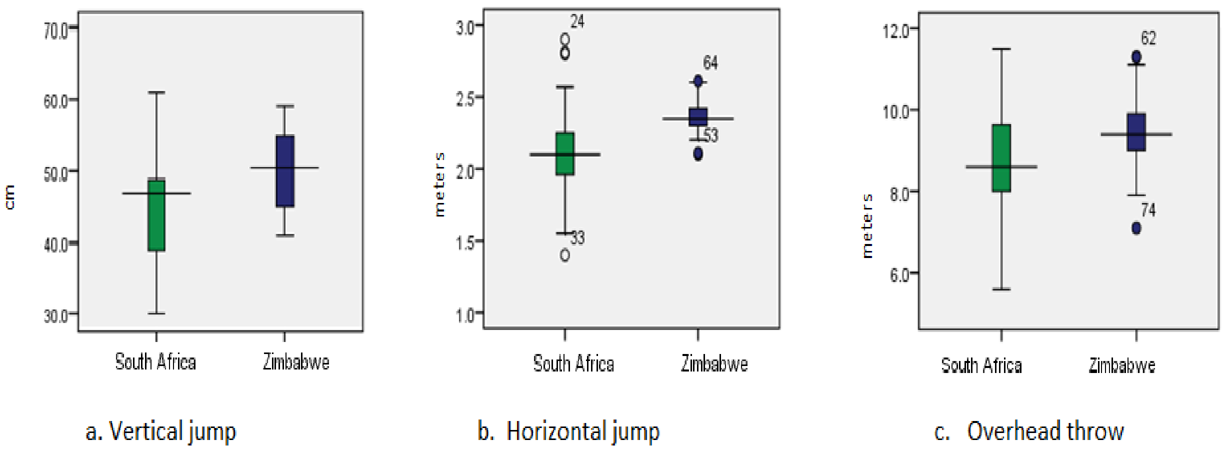


Figure 6.13. Comparative upper and lower body power of South African and Zimbabwean players

b. Upper and lower body power: South Africa and Zimbabwe combined according to position of play (values are mean ± SD)

There was a statistically significant difference in overhead power throw among playing positions (p = 0.05), while there were no statistically significant differences in vertical jump and horizontal jump performance (p > 0.05) (Table 6.18). On vertical jump, goalkeepers scored the highest scores, defenders, midfielder and forwards had similar scores (46cm). Goalkeepers performed best in the overhead power throw test, followed by forwards, midfielders and defenders. On horizontal jump, goalkeepers and defenders scored highest scores, while forwards and midfielders had the lowest scores.

Table 6.18. Upper and lower body power of South African (n=41) and Zimbabwean (n=33) players according to playing positions (values are mean ± SD)

Test	Goalkeepers (n=10)	Defenders (n=21)	Midfielders n=23)	Forwards (n=20)	P – value
Vertical jump (cm) cm	47.2±8.11	46.2±5.42	46,2±5.69	46.2±8.18	> 0.05
Horizontal jump (m)	2.3±0.44	2.2±0.24	2.3±0.30	2.2±0.34	> 0.05
Overhead throw (m)	10.0±1.10	8.7±1.13	8.9±1.34	9.1±1.41	= 0.05

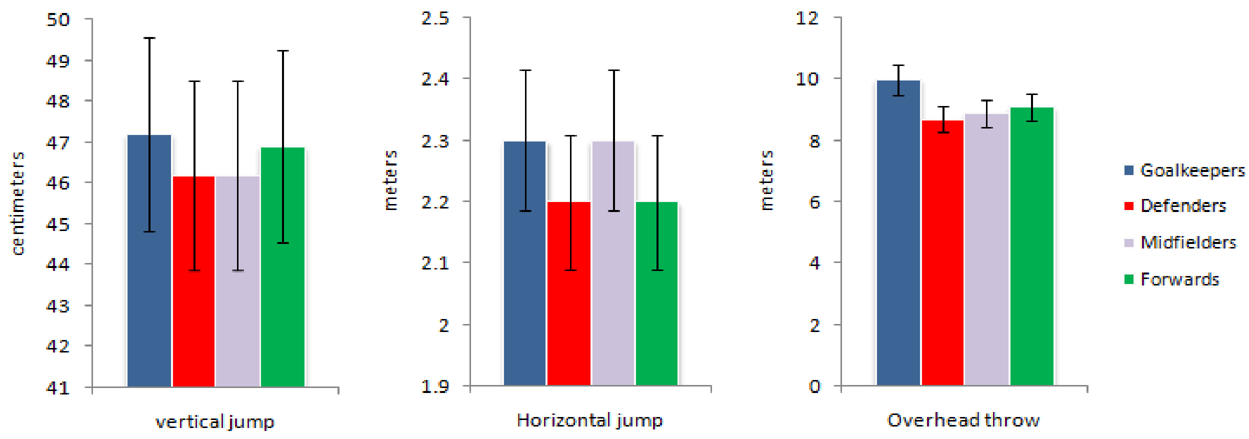


Figure 6.14. Comparative upper and lower body power of South African and Zimbabwean all playing positions combined.

c. Upper and lower body power: South Africans according to positions of play

There were no statistically significant differences across playing positions in the South African team for the three power tests (Table 6.19). Defenders had the highest explosive leg power (vertical jump) and goalkeepers had the least scores; midfielders and forwards had similar scores (44.2cm). Midfielders scored the least in horizontal jump while goalkeepers, defenders and forwards score the highest scores. Goalkeepers performed best in the overhead power throw compared to other players in the team, while midfielders had the least throwing distance.

Table 6.19. Upper and lower body power of South Africans according to playing positions (values are mean ± SD)

Test	Goalkeepers (n=10)	Defenders (n=21)	Midfielders (n=23)	Forwards (n=20)	P- value
Vertical jump (cm)	41.2±6.0	46.1±5.92	44.2±5.63	44.2±8.79	> 0.05
Horizontal jump (m)	2.1±0.44	2.1±1.22	1.9±0.30	2.1±0.41	> 0.05
Overhead throw (m)	9.6±1.32	8.6±1.22	8.4±1.51	8.7±1.72	> 0.05

d. Upper and lower body power: Zimbabweans according to positions of play

From Table 6.20, There were no statistically significant differences (p>0.05) noted in any of the three power tests across playing positions among Zimbabwean players. Goalkeepers had the highest values on all three tests, while forwards scored the least in the horizontal jump test.

Table 6.20. Upper and lower body power of Zimbabweans according to playing positions (values are mean ± SD)

Characteristics	Goalkeepers n=5	Defenders (n=7)	Midfielders (n=11)	Forwards (n=10)	P-value
Vertical jump (cm)	53.1±4.81	46.3±4.69	48.3±5.25	52.3±5.56	> 0.05
Horizontal jump (m)	2.4±0.20	2.4±0.72	2.4±0.88	2.3±0.11	> 0.05
Overhead throw (m)	10.4±0.84	8.7±0.92	9.5±0.90	9.5± 0.75	> 0.05

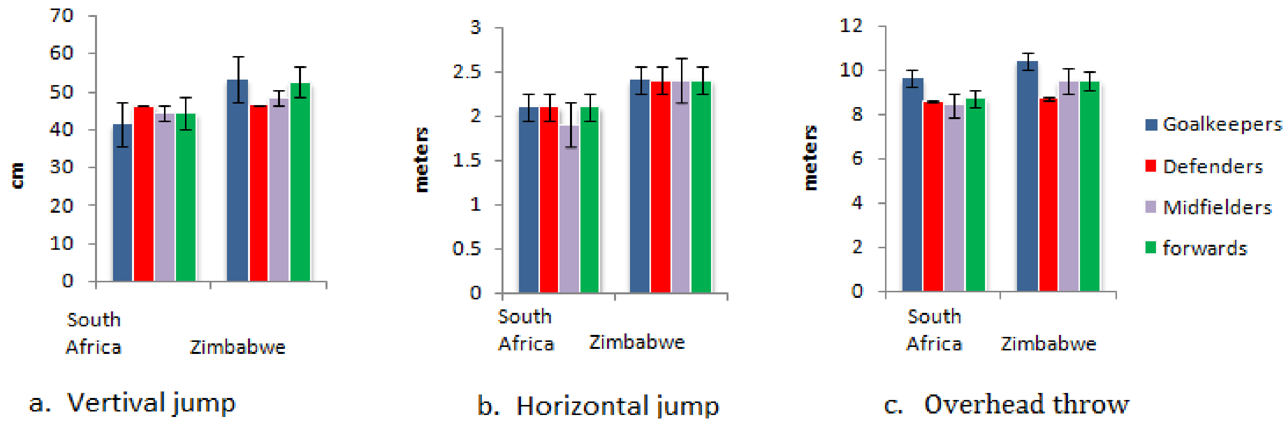


Figure 6.15. Comparative upper and lower body power of South African and Zimbabwean players according to position of play

3. Speed and agility

a. Speed and agility: South Africa and Zimbabwe

Zimbabwean players performed statistically significantly better in the agility test, 10m and 40m sprint tests compared to the South Africans. There were statistically significant differences between the two groups in agility and 10m ($p = 0.01$) and 40m sprints ($p < 0.001$).

Table 6.21 shows that there was no statistically significant difference in 20m sprint test among the two groups ($p > 0.05$). In Figure 6.16, South Africa had one outlier who performed exceptionally well in 10m sprints than the rest of the players. While both teams had outstanding performers in 20m and 40m, Zimbabwe had one player who performed extremely below the mean score.

Table 6.21. Speed and agility performance of South African (n = 41) and Zimbabwean (n = 33) players (values are mean + SD)

Test	Total	South Africa	Zimbabwe	P-value
Agility (sec)	16.7±0.72	16.9±0.88	16.5±0.37	= 0.01
10m Sprint (sec)	1.7±0.17	1.8±0.20	1.7±0.10	= 0.01
20m Sprint (sec)	3.0±0.28	3.0±0.34	3.0±0.17	> 0.05
40m Sprint (sec)	5.5±0.32	5.7±0.33	5.4±0.21	< 0.001

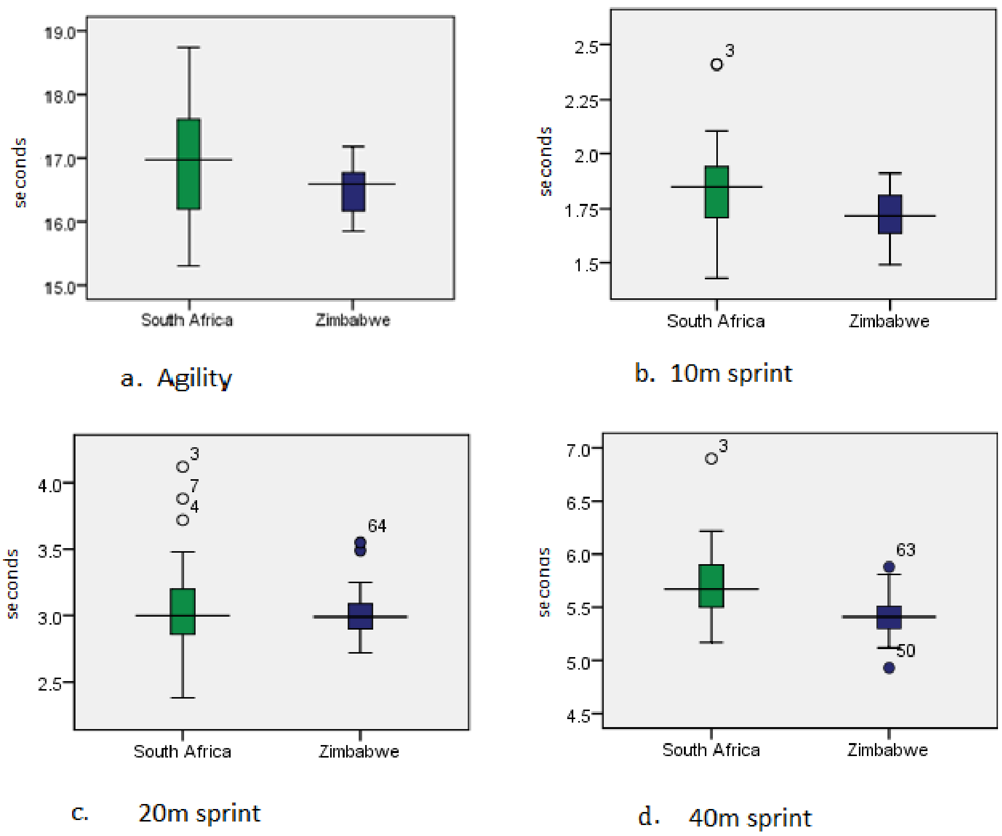


Figure 6.16. Comparative speed and agility scores: South African and Zimbabwean players

b. Speed and agility: South Africa and Zimbabwe according to positions of play

When South African and Zimbabwean players were combined into one group according to playing positions, there were no significant differences observed in agility or sprint performance ($p > 0.05$) (Table 6.22). However, goalkeepers were the most agile group while defenders were the slowest in terms of agility. Midfielders and forwards had similar agility scores. Figure 6.17 shows that midfielders and forwards had similar scores in 10 and 40m sprint test (1.7 and 5.5 seconds), while goalkeepers and defenders also had similar scores in the same test (1.8 and 5.6 seconds). In the 20m sprint test, goalkeepers and forwards scored better than defenders and midfielders.

Table 6.22. Speed and agility performance of the total group according to playing positions (values are mean ± SD)

Test	Goalkeepers (n=5)	Defenders n=7)	Midfielders (n=11)	Forwards (n=10)	P-value
Agility (sec)	16.6±0.60	16.8±0.79	16.7±0.76	16.7±0.72	> 0.05
10m sprint (sec)	1.8±0.15	1.8±0.23	1.7±0.15	1.7±0.13	> 0.05
20m sprint (sec)	2.9±0.27	3.1±0.36	3.0±0.21	2.9±0.25	> 0.05
40m sprint (sec)	5.6±0.30	5.6±0.41	5.5±0.27	5.5±0.29	> 0.05

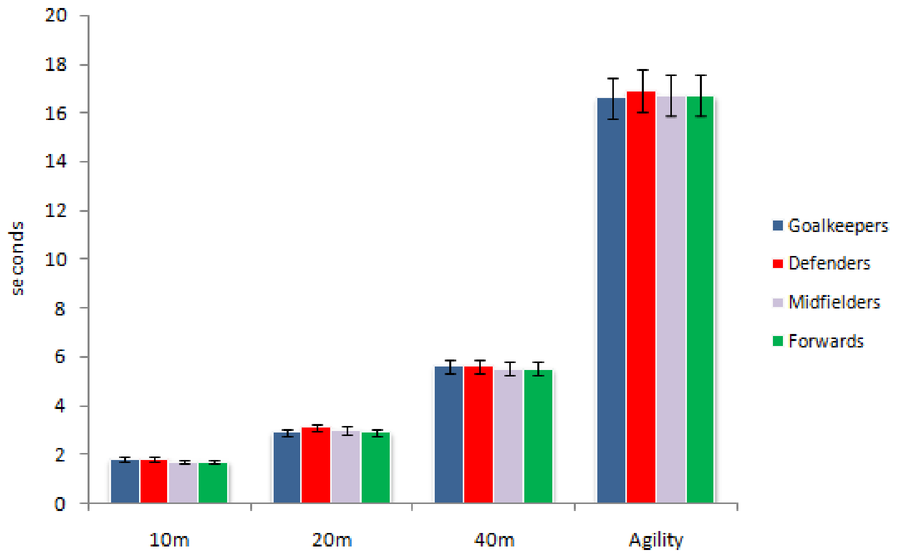


Figure 6.17. Comparative speed and agility scores of South African and Zimbabwean players all playing positions combined.

c. Speed and agility: South Africa according to position of play

There were no significant statistically significant differences across playing position ($p > 0.05$) for the South African team in terms of agility and all sprint performance tests. From Table 6.23, in agility, goalkeepers were the quickest followed by forwards while defenders and midfielders were the slowest. Midfielders and forwards were the fastest in the 10m sprint, while defenders and goalkeepers were the slowest (with similar score). Goalkeepers were the fastest in 20m sprints followed by midfielders and forwards while defenders were the least of all the playing positions. Figure 6.18d shows that forwards were the fastest over 40m, while all the other positions had similar times.

Table 6.23. Speed and agility performance of South Africans according to playing positions (values are mean ± SD)

Test	Goalkeepers (n=5)	Defenders (n=14)	Midfielders (n=12)	Forwards (n=10)	P-value
Agility (sec)	16.6±0.90	17.0±0.81	17.0±0.93	16.8±0.97	> 0.05
10m sprint (sec)	1.8±0.22	1.8±0.24	1.7±0.20	1.7±0.12	> 0.05
20m sprint (sec)	2.8±0.25	3.2±0.41	2.9± 0.22	3.0±0.35	> 0.05
40m sprint (sec)	5.7±0.36	5.7±0.38	5.7±0.29	5.6±0.30	> 0.05

d. Speed and agility: Zimbabwe according to position of play

Defenders were more agile than others players in the Zimbabwean team, followed by midfielders and forwards, while defenders were the least agile among the group. However, overall, there were no statistically significant differences across playing positions in terms of agility and sprint performance (p>0.05) (Table 6.24). Figure 6.18b shows that defender, midfielders and forwards had highest and similar scores in 10m sprints while goalkeepers had the least scores. In 20m sprints, defenders were the fastest groups followed by forwards, while goalkeepers and midfielders were the slowest among the group. In Table 6.24, defenders recorded the best sprint performance in 40m, followed by midfielders and forwards who had similar scores (5.4 seconds), while goalkeepers were the slowest.

Table 6.24. Speed and agility performance of Zimbabweans according to playing positions (values are mean + SD)

Test	Goalkeepers n=5	Defenders (n=7)	Midfielders (n=11)	Forwards (n=10)	P – value
Agility (sec)	16.7±0.78	16.3±0.41	16.5±0.39	16.6±0.35	> 0.05
10m sprint (sec)	1.8±0.08	1.7±0.11	1.7±0.80	1.7±0.13	> 0.05
20m sprint (sec)	3.1±0.26	2.9±0.12	3.1±0.20	3.0±0.10	> 0.05
40m sprint (sec)	5.5±0.19	5.3±0.26	5.4±0.17	5.4±0.21	> 0.05

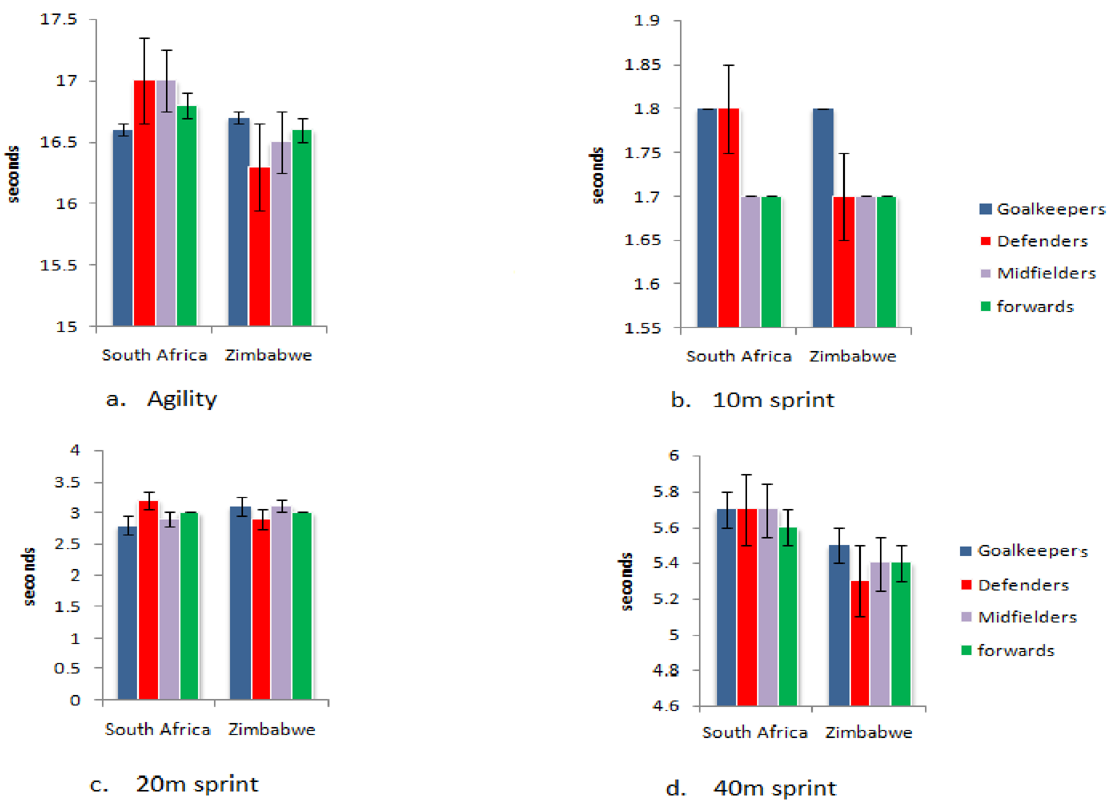


Figure 6.18. Comparative speed and agility of South African and Zimbabwean players according to position of play

4. Endurance capacity

a. Endurance capacity of South Africa and Zimbabwe

The Zimbabwean players had better endurance compared to the South African players (Table 6.25). The endurance test results from the Hoff's test showed no significant difference in the distance covered by the two teams and the corresponding estimated VO_{2max} ($p>0.05$), although the Zimbabwean players covered a further distance compared to their South African counterparts.

Table 6.25. Endurance capacity of South African (n = 41) and Zimbabwean (n = 33) players (values are mean + SD)

Test	Total (74)	South Africa	Zimbabwe	P-value
Hoff's test (m)	1563.7±123.6	1549.0±134.3	1581.0±108.4	> 0.05
VO_{2max} (ml/kg/min)	61.1±6.23	60.5±6.88	61.8±5.34	> 0.05

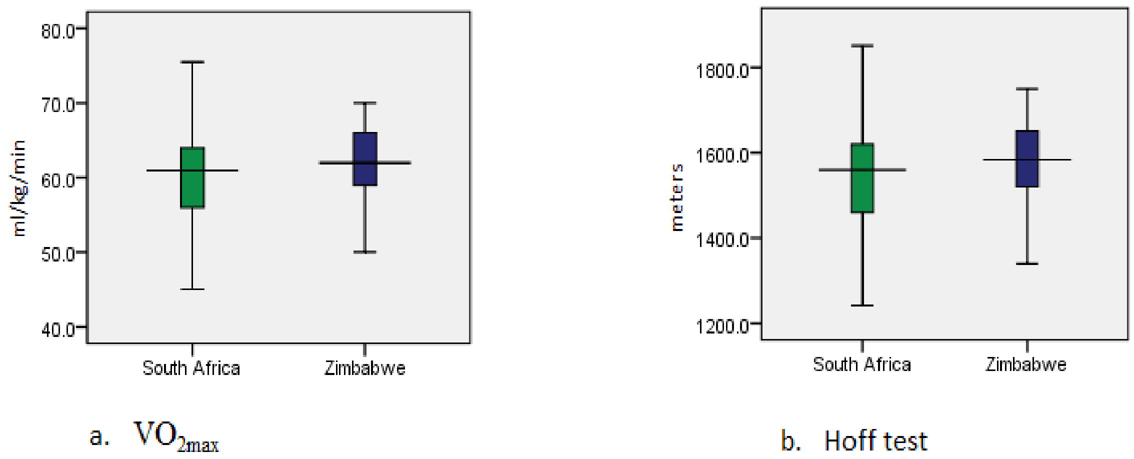


Figure 6.19. Comparative endurance capacity of South African and Zimbabwean players

b. Endurance capacity: South Africa and Zimbabwe combined according to positions of play

Midfielders completed the furthest distance in the Hoff test, and had the highest estimated VO_{2max}, followed by defenders and goalkeepers (Table 6.26). Forwards completed the shortest distance among the groups meaning that they have low endurance capacity among the group. However, no statistically significant differences were observed across playing positions (p = 0.07) for either distance achieved or estimated VO_{2max}.

Table 6.26. Endurance capacity of South African (n = 41) and Zimbabwean (n = 33) players (values are mean ± SD)

Test	Goalkeeper (n=10)	Defender (n=21)	Midfielders (n=23)	Forwards (n=20)	P - value
Hoff's Test (m)	1572.4±101.1	1554.2±120.9	1609.7±118.3	1516.5±131.3	> 0.05
VO_{2max}	61.6±5.12	60.5±5.9	63.7±6.09	58.8±6.52	> 0.05

c. Endurance capacity: South Africa according to position of play

There was no statistically significant difference in endurance capacity of South African players according to positions of play (p > 0.05) (Table 6.27). However midfielders had the highest estimated VO_{2max} as well as furthest distance compared to other positions, followed by defenders and goalkeepers, while forwards had the lowest distance and estimated VO_{2max} among the groups. (Figure 6.20a-b).

Table 6.27. Endurance capacity of South Africans according to playing positions (values are mean ± SD)

Test	Goalkeeper (n=5)	Defender (n=24)	Midfielders (n=12)	Forwards (n=10)	P - value
Hoff's Test (m)	1513.4± 89.9	1541± 133.1	1628.7±132.2	1484.9±125.5	> 0.05
VO_{2max}	58.6±4.54	60.0±6.65	64.8±6.91	57.2±6.26	> 0.05

d. Endurance capacity: Zimbabwe according to position of play

There was no difference in VO_{2max} performance for the Zimbabwean team across playing positions ($p > 0.05$), although goalkeepers had the highest VO_{2max} compared to the other positions followed by midfielders and defenders. Forwards covered the smallest distance and had the lowest estimated VO_{2max} among the group (Table 6.28).

Table 6.28. Endurance capacity of Zimbabweans according to playing positions

Test	Goalkeepers n=5	Defenders (n=7)	Midfielders (n=11)	Forwards (n=10)	P-value
Hoff's test (m)	1631.40± 78.56	1580.00± 95.70	1588.91± 103.15	1548.10± 135.75	> 0.05
VO_{2max}	64.60± 4.03	61.28±4.53	62.36±5.04	60.30±6.70	> 0.05

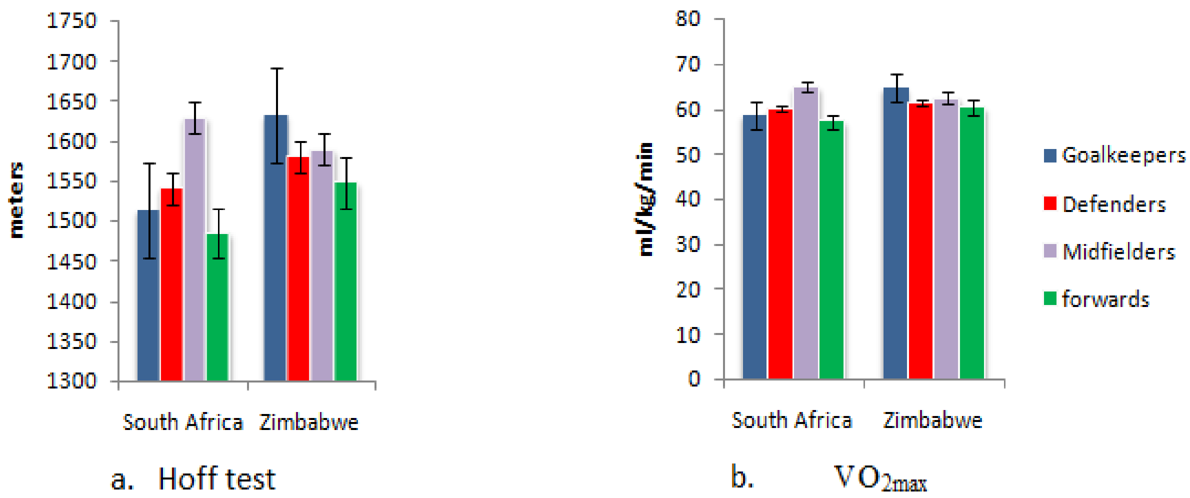


Figure 6.20. Comparative endurance capacity of South African and Zimbabwean players all position of play combined.

D. Correlation between body composition and functional fitness variable

A Pearson product moment correlation was used to determine the relationships between selected body composition and physical performance. Statistically significant correlations are marked by asterisks (*).

1. Correlation between body composition and flexibility

According to Table 6.29 flexibility (sit and reach, right and left shoulder flexibility) was not related to the body mass of players, height, sum of skinfolds, body density (Db), percentage body fat (%BF), waist hip ratio (WHR), body mass index (BMI).

Table 6.29. Correlation between body composition and flexibility

N - 74	**Mass.** *r-value* *(p-value)*	**Height** *r- value* *(p-value)*	**Σ of SKF** *r-value* *(p-value)*	**BD** *r-value* *(p-value)*	**%BF** *r-value* *(p-value)*	**WHR** *r-value* *(p-value)*	**BMI** *r-value* *(p-value)*
SR	-0.04 (0.75	-0.11 (0.35)	-0.05 (0.66)	0.04 (0.72)	-0.04 (0.72)	0.02 (0.88)	0.10 (0.39)
SFR	-0.20 (0.09)	0.01 (0.92)	-0.14 (0.23)	0.21 (0.08)	-0.21 (0.08)	0.01 (0.97)	0.16 (0.19)
SFL	-0.21 (0.08)	0.01 (0.91)	-0.09 (0.45)	0.13 (0.29)	-0.13 (0.28)	-0.03 (0.84)	0.15 (0.20)

* P < 0.05. SR-sit and reach; SFR-right shoulder flexibility; SFL-left shoulder flexibility

** P < 0.01.

2. Correlation between body composition and power

From Table 6.30, statistically significant correlations were found between body composition variables [mass of players, height, sum of skinfolds, body density (Db), percentage body fat (%BF)] and explosive power (vertical jump, horizontal jump and overhead throw). (All players combined). A positive correlation was noted between vertical jump and height of players as well as on vertical height and body density, horizontal jump and body density, overhead throw and mass as well as overhead throw and height. Vertical jump was negatively related to sum of skinfolds and %BF while horizontal jump, sum of skinfolds and %Bf were also negatively correlated

Table 6.30. Correlation between body composition and power

N – 74	**Mass.** *r-value* *(p-value)*	**Height** *r- value* *(p-value)*	**Σ of 8SKF** *r-value* *(p-value)*	**Db** *r-value* *(p-value)*	**%BF** *r-value* *(p-value)*	**WHR** *r-value* *(p-value)*	**BMI** *r-value* *(p-value)*
VJ	0.11 (0.37)	**0.27*** (0.02)	**-0.39**** (0.00)	**0.27*** (0.02)	**-0.28*** (0.02)	0.02 (0.85)	0.13 (0.27)
HJ	-0.06 (0.60)	0.08 (0.52)	**-0.58**** (0.00)	**0.58**** (0.00)	**-0.57**** (0.00)	-0.04 (0.76)	0.16 (0.19)
OHT	**0.43**** (0.00)	**0.43**** (0.00)	0.00 (0.99)	0.01 (0.97)	0.00 (0.98)	0.08 (0.52)	0.17 (0.16)

* P < 0.05. VJ-vertical jump; HJ-horizontal jump; OHT-overhead throw

** P < 0.01.

3. Correlation between body composition, speed and agility

Statistically significant correlations were found between body composition variables [mass of players, sum of skinfolds, body density (Db), percentage body fat (%BF, waist hip ratio (BMI)] and explosive power (agility and sprint test results). Positive correlations were observed between agility, 10m, 40m sprints and %BF, 10m, 20m sprints and body mass, 10m, 40m sprints and sum of skinfolds as well as between 40m sprint and body density. Negative correlations were noted between agility, 10m and body density as well as between 40m sprint and BMI.

Table 6.31. Correlation between body composition, speed and agility

	Mass *r-value* *(p-value)*	**Height** *r- value* *(p-value)*	**Σ 8 SKF** *r-value* *(p-value)*	**BD** *r-value* *(p-value)*	**%BF** *r-value* *(p-value)*	**WHR** *r-value* *(p-value)*	**BMI** *r-value* *(p-value)*
Agility	-0.08 (0.48)	-0.03 (0.84)	0.14 (0.22)	**-0.24*** (0.04)	**0.24*** (0.04)	-0.21 (-0.07)	0.04 (0.75)
10m sprint	**0.24*** (0.04)	-0.06 (0.61)	**0.36**** (0.00)	**-0.34**** (0.00)	**0.34**** (0.00)	-0.01 (0.96)	-0.13 (0.29)
20m sprint	**0.25*** (0.03)	0.04 (0.73)	0.18 (0.12)	-0.22 (0.57)	0.22 (0.06)	0.11 (0.34)	-0.03 (0.83)
40m sprint	0.17 (0.16)	-0.02 (0.87)	**0.45**** (0.00)	**0.40**** (0.00)	**0.41**** (0.00)	-0.05 (0.65)	**-0.26*** (0.03)

* $P < 0.05$

** $P < 0.01$

4. Correlation between body composition and endurance

It was noted that body composition variables [mass of players, height, sum of skinfolds, body density (Db), percentage body fat (%BF), waist hip ratio (WHR), body mass index (BMI)] were not correlated to VO_{2max} and distance covered during the Hoff test.

Table 6.32. Correlation between body composition and endurance

N – 74	**Mass.** *r-value* *(p-value)*	**Height** *r- value* *(p-value)*	**Σ 8 SKF** *r-value* *(p-value)*	**BD** *r-value* *(p-value)*	**%BF** *r-value* *(p-value)*	**WHR** *r-value* *(p-value)*	**BMI** *r-value* *(p-value)*
Hoff test	0.04 (0.72)	0.120 (0.31)	-0.132 (0.26)	0.09 (0.46)	-0.09 (0.43)	-0.01 (0.93)	-0.08 (0.48)
VO_{2max}	0.05 (0.66)	0.15 (0.21)	-0.12 (0.33)	0.07 (0.57	-0.07 (0.54)	-0.01 (0.93)	-0.08 (0.52)

* P < 0.05

** P < 0.01

CHAPTER 7

DISCUSSION

A. Introduction

The purpose of the study was to compare body composition, somatotype and functional fitness characteristics of South African and Zimbabwean young academy soccer players and distinguish variables that can be used to predict future successful performance in soccer. The anthropometric variables that were assessed included height, weight and body composition (sum of eight skinfolds, cirumferences and bone breadths), from which the following derived body composition variables were assessed; % body fat, body density, fat mass and fat mass index, fat free mass, and fat free mass index, body mass index, waist-hip ratio and somatotype. Functional capacity variables that were assessed included; flexibility, upper and lower body power, speed, agility and aerobic endurance. This discussion is therefore focusing on how the results obtained for the two teams are comparable to one another and how they can be used in talent selection as well as how they compare to findings of similar studies in the literature.

B. Research participants

Seventy four (74) players were purposively selected to participate in the study. The study included only players from selected soccer academies in South Africa and Zimbabwe who volunteered to participate. Forty one (41) players were selected from South African teams and thirty three (33) from Zimbabwean teams. The South African teams played in the Western Cape Province junior league and they trained twice per week. The average age of the South African players was 16.4±0.94 years and they had an average experience in organised soccer of 5.4 years. The sample consisted of 5 goalkeepers; 14 defenders; 12 midfielders; and

10 forwards/strikers. Of the 33 Zimbabwean players, seventeen (17) played in the Zimbabwe Football Association first division, while the other 16 played in the Harare Region junior league. The average age of the Zimbabwean players was 16.5±0.70 years and they had an average of 5.7 years of exposure to organised soccer. Three of the players play for the Zimbabwe National under 17 team. All the Zimbabwean players train four days per week and they play league matches over the weekends. The team comprised of 5 goalkeepers; 7 defenders; 11 midfielders; and 10 forwards/strikers.

There was no significant difference in the players' age ($p = 0.79$), but the Zimbabwean players were statistically significantly advanced in maturity ($p = 0.03$). The teams did not differ significantly in the length of period exposed to organised soccer ($p = 0.43$). However, the first 17 players had exposure to higher levels of competitive soccer than other players by virtue of playing in the first division, but the remaining 16 were comparable in playing level with their South African counterparts. The limitation of this study sample is that, by nature of being a purposive sample it cannot be generalised to represent all the South African and Zimbabwean junior team players, hence the research findings only apply to these selected groups.

C. Anthropometric characteristics

1. Height and weight

Height and weight are reportedly determined more by heredity (Malina *et al*., 2004; Bouchard *et al*., 1997) and to some extent by environmental factors and life style. The use of height and weight in talent selection in soccer is limited as soccer players are known to have varying heights and weights, however, it was reported that height and weight of players have a positional advantage (Reilly *et al*., 2000a). Tall and heavy players were noted to feature as goalkeepers and central defenders, while short and light players play as midfielders and forwards (Reilly *et al.*, 2000a; Bangsbo, 1994a).

In the current study, there was no statistically significant difference in height and weight between South African and Zimbabwean players ($p > 0.05$). Goalkeepers and defenders were found to be the tallest and heaviest while forwards and midfielders were the shortest in the team. This shows a common tendency in many soccer teams to allocate positional roles to players based on anthropometric characteristics.

The mean height and weight for South African and Zimbabwean teams combined together was 169.7±5.89 and 59.9±8.47, respectively. When mean height and weight scores found in this study is compared to data of young soccer players of similar age groups from the literature in other studies, they reflect that players from South African and Zimbabwe compared well with players from China elite under 17 soccer team studied by Wong and Wong (2009); the Brazilian under 16 soccer team reported by Pittoli *et al*. (2010) and the Canadian under 16 team reported by Leatt *et al*. (1987). However, it was noted that the height and weight results of young soccer players in this study are significantly lower to those of young soccer players from Tunisia and Senegal studied by Chamari (2004) and those of young players from Finland reported by Rahkila and Luthanen (1989), as well as those from Europe reported by Hegerud *et al*. (2001). It was noted that young players from these countries are taller and heavier than those in the current study.

2. Body composition and somatotype

There were significant differences between the South African and Zimbabwean players in terms of the sum of 8 skinfolds ($p = 0.01$), WHR ($p = 0.02$), %BF ($p = 0.03$), FFM ($p < 0.001$) and body density ($p = 0.03$). No significant differences were noted for BMI ($p = 0.08$), FM and FMI ($p > 0.05$). There were no data on Waist:Hip ratio, fat mass index, fat free mass index and sum of 8 skinfolds in the literature to compare the findings of the current study with.

Percentage body fat of South African players was 10.5 ± 3.61% and for Zimbabwean players was 9.0 ± 1.6%. South Africans had significantly higher %BF, SSKF, FM and FMI, mainly because of 3 players who had greater individual values on these variables than the other players in the team. The lower %BF, SSKF, FM and FMI and higher FFM of Zimbabwean players could be attributed to factors like training status of the team, which was found to train more days per week than the South African team, and also to the level of competition for the 17 Zimbabwean players who played for first division league. Due to higher competition demands in the first division they can present with less fat mass which could have contributed to lower averages for the whole team on these variables. This assumption is consistent with the findings of Koutedakis (1995) who noted that players at a higher level of competition have less %BF and FM levels compared to players at lower levels of competition.

Zimbabweans were found to have higher values of WHR (0.84 ± 0.03) and BMI (21.4 ± 1.39) compared 0.80 ± 0.07 and BMI 20.5 ± 2.51 for South Africans. However, the Zimbabwean players were found to have low %BF and FM values. This was unusual since WHR and BMI variables are functions of %BF and FM and they were expected to be higher also. However, this could be related to the weakness of BMI as a measure of adiposity since it does not consider whether the total body mass is composed more of muscle mass or fat mass.

In the present study there was no significant difference between players in different playing positions (goalkeepers, defenders, midfielders and forwards) in %BF, sum of SKF, body density, BMI, WHR, and FM, although goalkeepers had higher adiposity compared to defenders, midfielders and strikers. Strikers had the least %BF, Σ8SKF, and FM. This was the similar trend reported by Salgado *et al*. (2008). Reilly *et al*. (2010) also reported similar results on goalkeepers, but with a significant difference ($p < 0.001$) between goalkeepers and other playing positions. They found that the other players (defenders, midfielders and forwards) were not different in adiposity. This could be due to the fact that the positional role of goalkeepers does not demand a lot of running during match situations and during training goalkeepers could have been given their own training sessions different from the rest of the players in other positions - a common practice in most soccer team (unpublished source).

In the present study, it was noted that goalkeepers were bigger and more muscular (balanced mesomorphs) than players in other positions, followed by defenders who were in the mesomorphic ectomorphic category. Midfielders and forward were in the same category, namely mesomorph-ectomorphs (muscular and leaner). This is similar to the findings of Salgado *et al*. (2008) (Portuguese) and Gil *et al*. (2007) who reported a similar trend for young Spanish soccer players. It is a common characteristic of soccer players to possess the mesormorphic component (Reilly *et al*., 2000).

Nonetheless, the values for both countries were found to be within the normal range but above that of 15 year old young soccer players from Spain reported by Moreno *et al*. (2004). The mean percentage body fat for both teams in the current study was 9.9 ± 3 %. This was higher than the 6.0 ± 2.7% of young Zimbabwean soccer players reported by Makaza *et al*. (2012), but within the range of 9.6 ± 3.0 % reported by Tahara *et al*. (2006) for Japanese young soccer players and 10.1 ± 0.8 % of Portuguese junior soccer players. However, the results were below (better) than the 11.9% for elite French academy players reported by Le-Gal *et al*. (2010), 10.6 ± 2.6% for young soccer players from Denmark reported by Reilly *et al*. (2010), 15.64 ± 3.8% for young Spaniards reported by Moreno *et al*. (2004) and 16.1 ± 4.3% for young players from Portugal reported by Salgado *et al*. (2008). Fat mass for the current study was 6.0 ± 2.68 kg, which is below the 15.3±5.6 kg of young players from Portugal reported by Salgado *et al*. (2008).

The source of these different results reported by different authors could be the use of different %BF prediction equations or the use of different body composition assessment methods. It was noted that those whose results were in the same range had use similar prediction equations and body composition assessment methods.

D. Functional Fitness Capacity

1. Flexibility

Although flexibility can be considered important in soccer, several studies reported that it is very weak in determining future performance in young players (Signorelli *et al*., 2012; Ostojic and Stojanovic, 2007; Malina *et al*., 2004). The most common flexibility method used in soccer is the sit and reach test, however the current study incorporated sit and reach and the left and right shoulder flexibility tests. No literature was found where the shoulder flexibility test has been used in young soccer players, hence there are no reference score for this test. However, considering the rapid movements of the upper body during dribbling and turning and the explosive throwing actions during throw-ins during a soccer match, this test should actually be considered for young soccer players.

In the shoulder flexibility tests, the South African players showed better performance over their Zimbabwean counterparts. They recorded 10.2 ± 7.82cm on the right shoulder and 6.6 ± 7.26 on the left shoulder, against Zimbabwean scores of 8.3 ± 4.70 and 2.4 ± 7.24. No statistically significant differences were observed in all the flexibility tests between the South African and Zimbabwean players, except in left shoulder flexibility ($p < 0.01$). South African players showed superior performance over Zimbabwean players in both right and left shoulder flexibility tests. The reason for this result could be that during training sessions coaches neglect flexibility drills and focus more on the technical and tactical components, hence the significant difference noted in left shoulder flexibility between the two teams could be by fate. Goalkeepers were found to be more flexible than the other players. This could be due to positional demands since the goalkeeper is expected to catch balls from different directions and from different angles. No specific literature was found that compares flexibility according to playing positions in soccer.

Table 7.1: Comparative sit and reach flexibility results of the current study and studies in the literature

Study	Level /Age	Findings
Gray and Jenkins (2010) Australian	Professionals	10.7 ±6.4 cm
Young and Pryor (2007) Australia	Selected elite juniors	8.8 ± 7.5 cm
	Non-selected juniors	7.1 ±7.3 cm
Signorelli *et al*., (2012). Brazil	Young elite	14.3 ±3.2 cm
	Young non-elite	13.1 ±4.4 cm
Nikolaïdis (2012). Greece.	12 years	16.6±5.1 cm
	Under 16 juniors	20.7±7.5 cm
Current study	**17 years**	**9.6±7.75 cm**

The flexibility results of South Africa and Zimbabwe (combined) are comparable to those reported by Young and Pryor (2007) for Australian elite juniors and Gray and Jenkins (2010) for Australian professional players (Table 7.1). South African and Zimbabwean players were found to be less flexible in the hamstrings and lower back compared to other players studied elsewhere. They had worse scores compared to Greek under 12 and 16 players studied by Nikolaïdis (2012); to Brazilian elite and non-elite junior players studied by Signorelli *et al*. (2012) and probably due to some of the reasons prior stated. Flexibility is regarded as an unreliable test to distinguish players of different performance abilities because it uses a non-qualitative ranking system ranging from low to high (Adams, 2002), whereby hyper-flexibility cannot be said to be optimal and neither can high flexibility scores be classified as excellent.

2. Power

Leg power forms the basis for successful performance in soccer because all the dynamic actions in a soccer match depend on the power generated from the lower body (e.g. sprinting, jumping, sprinting, kicking, heading the ball and jogging). All movements depend on the muscular power of the legs (Faigenbaum and Westcott, 2000).

In this study vertical and horizontal jump tests were used to assess explosive leg power. Upper body power was assessed using overhead medicine ball power throw. The use of the horizontal jump and medicine ball throwing in youth soccer is very limited. Researchers prefer the use of one repetition maximal tests to assess upper body power and vertical jump for lower body power. Therefore there was no literature to compare the horizontal jump and overhead power throw scores with.

The current research found that there were strong significant differences in all three power tests between the South African and Zimbabwean teams for vertical jump ($p = 0.001$); horizontal jump ($p < 0.001$) and overhead throw ($p = 0.01$). The Zimbabwean team scored higher values in all three power tests (Table 6.13). Helgerud *et al*., (2001) reported an association between explosive power and maturity. The difference in power scores could have emanated from the advanced maturity status of Zimbabwean players ($p = 0.03$)

compared to South Africans or it can be attributed to higher levels of adiposity which Malina *et al*. (2004) found to influence jumping abilities. The correlation analysis (Table 6.30) found that negative correlations exist between vertical jump results and %BF ($r = -0.28$, $p = 0.02$) and sum of skinfold ($r = -0.39$; $p < 0.001$). These variables were found to be higher in South African players and can be responsible for the lower jumping capacity of South Africans players. Goalkeepers were found to have higher explosive leg power compared to defenders, midfielders and forwards, a factor which can be attributed to positional duties. There were no differences in jumping scores between defenders, midfielders and forwards. The study found a positive relationship between height, body mass and the upper body power test. These variables were higher in Goalkeepers and could be the reason for goalkeepers to attain higher scores in the upper body power test than players in other playing positions.

Table 7.2: Comparative vertical jump results of the current study and studies in the literature

Study/country	Level / Age	Findings
Gerodimos *et al*., (2006). Greece	10-12 years	47.5±6.69 cm
Leatt *et al*., (1987). Canada	16-18 years	53±6.72 cm
White *et al*., (1988). England	Under 19	59.8±7.80cm
Wisloff *et al*., (2004). Norway	Under 18	56.4±7.70 cm
Tiryaki *et al*., (1997). Turkey	Elite juniors	54.1±7.60 cm
Current study	**Under 17**	**46.8±6.68 cm**

The vertical jump height of South Africans and Zimbabweans (combined) was higher than that of young players from Greece which were reported by Gerodimos *et al*. (2006).

However, they are low compared to the results of junior soccer players studied elsewhere, for example English junior players reported by *et al*. (1988), Norwegian young players reported by Wisloff *et al*. (2004) and Canadian junior players reported by Leatt *et al*. (1987). Although the present study could not distinguish performance differences between players from the two countries, vertical jump height was noted to be a relevant and reliable test to discriminate better performers and lesser performers in soccer (Gerodimos *et al*., 2006). Players with greater jumping abilities were found to hit high balls which cannot be easily intercepted by opponents (Young *et al*., 2007; Gerodimos *et al*., 2006), thus winning possession more than the low jumper (Ashley and Weiss, 1994).

3. Agility

Agility is a crucial component in soccer as players are required to frequently run quickly and rapidly change direction during a match in response to the bounce of the ball or in reaction to movement or anticipated movements of the opponent. Agility test scores were found to differentiate players of varying playing standards. Farrow *et al*. (2005) successfully used it on rugby players and Sporis *et al*. (2011) used it in netball.

There are various studies which used different instruments to measure agility (Chaleh-Chaleh *et al*., 2012; Sporis *et al*., 2011; Svensson and Drust, 2005; Buttifant *et al*., 1999; Moren, 1995). The current study used the Illinois agility test. The test incorporates both the aspect of acceleration and change of direction which characterise the actual running during a soccer match. Zimbabwean players scored statistically significantly better in the agility test compared to the South Africans (p = 001). This shows a difference in performance capabilities between the two groups and the Zimbabwean team can be assumed to have better opportunities for future success in soccer.

When comparing different playing positions, the current study found that there were no statistically significant differences between players in all positions of play (p>0.05). Strikers and midfielders were noted to be the most agile group, whilst defenders and goalkeepers were the least agile group Sporis *et al*. (2011) reported similar findings in a group of elite Serbian under 16 National team soccer players which they analysed according to playing positions. They similarly reported no significant differences between players in different playing positions.

Table 7.3. Comparative agility results of the current study and studies in the literature

Study	**Level / Age**	**Findings**
Mercer *et al*., (1998). Australian	Elite juniors	16.54 ± 4.5 sec
Chamari *et al.*, (2004). Tunisian	Under 17	17.7 ± 0.62 sec
Amiri and Fattahi, (2013). Iran	Under 19	16.65± 0.34sec
Kutlu *et al*., (2012). Turkey	Under 19	17.54±0.56sec
Current study	**Under 17**	**16.7±0.72 sec**

When agility results from this current study are compared to those of similar age-related players from elsewhere who were tested using the same battery (Illinios) (Table 7.3), the findings are within range with those reported by Amiri and Fattahi (2013) for Iranians. They are also better than those reported by Chamari *et al*. (2003) for Tunisians and those of Turkey players reported by Kutlu *et al*. (2012). Results that were reported by Mercer *et al*. (1998) show that Australian junior players were faster and more agile than players in the current study.

4. Speed

Speed is the ability to move the body or a body limb in the shortest possible time (Gambetta, 1990). It is one of the most important functional fitness characteristic in soccer, and has been known to directly contribute to winning ball possession and creating opportunities for goal scoring (Duthie *et al*., 2006). The most frequently used speed tests in assessing soccer players range between 5m and 60m, and the results from these tests can be used to differentiate between different standards of play, as well as allocating position of play in the team (Kollath and Quade, 1993).

In the current study 10m, 20m and 40m sprints were used to assess sprinting abilities of young players. There were statistically significant differences between the South African and Zimbabwean teams in 10m sprints ($p=0.01$) and 40m sprint ($p=0.01$) but no significant difference was observed for 20m sprint performance tests ($p>0.05$). The results show that Zimbabwean players were better performers compared to South African players. Lack of differences in 20m speed test scores between the South African and Zimbabwean teams is inconsistent with the findings of Valquer *et al*. (1998) who noted that short sprint bouts of less than 30m can best distinguish performance in soccer because they resemble the actual sprints in a soccer match.

When comparing different playing positions, the current study found that there were no significant differences between players in all positions of play. Strikers and midfielders were noted to be the fastest, whilst defenders and goalkeepers were the slowest in the 10m, 20m and 40m sprints - similar observation to Sporis *et al*. (2011). However in 20m sprint goalkeepers had similar top scores with strikers. Sporis *et al*. (2011) reported that playing positions do not differ significantly in straight line sprint tests. However, they noted that attackers displayed better speed, while goalkeepers were the slowest. Speed tests were found to discriminate good performers from lesser performers (Stolen *et al*., 2005; Valquer *et al*., 1998) and speed scores were reported to be good indicators of on-the-field performance for heterogeneous groups (Young *et al*., 2005). The 10m and 40m sprint tests successfully discriminated between South African and Zimbabwean young soccer players. The findings are consistent with those of Wong *et al*. (2005) who studied Australian junior soccer players and found differences in sprint time (p = 0.02 in 10m; p = 0.04 in 40m) between starters and substitutes, Commetti *et al*. (2001) who studied elite and sub-elite French players and Pyne *et al*. (2005) who studied selected and non-selected (from an academy to upper levels of play) Australian junior soccer players.

Table 7.4. Comparative speed results of the current study and studies in the literature

Study	Level / Age	10m (sec)	20m (sec)	40m (sec)
Diallo *et al.*, (2001) France	12-13 years	1.88±0.10	3.15±0.12	
Chamari *et al.*, (2004). Tunisia and Senegal	Juniors	1.87±0.1		
Helgerud *et al.*, (2001). Norway	Juniors	1.88±0.06	3.13±0.10	5.58±0.16
Hoff and Helgerud, (2002). Norway	Division 2	1.91±0.07		5.68±0.21
Current study	**Under 17**	**1.7±0.17**	**3.0±0.28**	**5.5±0.32**

The sprint times from the current study reflect superior performance by teams compared to age-matched players from other countries (Table 7.4). There is also no noticeable difference in 40m speed reported in this study and the one by Helgerud *et al.* (2001) for Norwegian young players.

5. Endurance

The current study used the Hoff test to assess the endurance capacity of players. The results showed that there was no significant difference between the South African and the Zimbabwean young soccer players, although the Zimbabwean team had higher VO_{2max} values than the South Africans and covered a greater distance in the Hoff test compared to South Africans. This could be due to similarities in the level of experience of the players in organised soccer training, as there was no significant difference (p=0.43) in the number of years of exposure to organised soccer between the two teams. The other reason could be the training status of the teams. Both teams can be considered sub-elite and Helgerud *et al*. (2001) reported that players of similar training status cannot be distinguished using $VO_{2max.}$ The small difference between the South African (60.5 ± 6.88 ml/kg/min and 1549.0 ± 134.3m) and Zimbabwean teams (61.8 ± 5.34 ml/kg/min and 1581.0 ± 108.4m) in VO_{2max} and distance covered in the Hoff test can be due to the higher level of competition of 17 Zimbabwean players who played in the first division league and the frequency of training. The Zimbabwean players trained 4 days a week and played league games over the weekend and the South Africans trained 2 days per week. Gil *et al*. (2007) propounded that as the level of competition increases, the demand for increased VO_{2max} also becomes higher.

Midfielders showed higher VO_{2max} (63.6 ± 6.09 ml/kg/min) and covered further distances in the Hoff test (1609.7 ± 118.29m) compared to players in other positions of play. Forwards had the lowest scores (58.7 ± 6.51ml/kg/min and 1516.5 ± 131.31m)

Table 7.5: Comparative VO_{2max} results of the current study and studies in the literature

Study	Level / Age	VO_{2max}
Gil *et al*., (2007). Spain	Elite juniors	62.4 ml/kg/min
Chamari *et al*., (2004). Tunisia and Senegal	Under 19	61ml/kg/min
Ostojic, (2003). Yugoslavia	Elite seniors	52.9 ± 9.1 ml/kg/min
Hoff *et al*., (2002) Norway	Division 2	63.3 ml/kg/min
Helgerud *et al*., (2001) Hungary	Under 18	73.9 ml/min/kg
Rahkila and Luthanen, (1989) Finland	17-18 years	56m/kg/min
Leatt *et al*., (1987) Canada	Under 18	57ml/min/kg
Current study	**Under 17**	**61.1±6.23 ml/kg/min**

The VO_{2max} values (Table 7.5) are similar to those of Tunisians and Senegalese players reported by Chamari *et al*. (2004), Spanish junior players reported by Gil *et al*. (2010) and Norwegians reported by Hoff *et al*. (2002). However, they were found to be lower to those for Hungarians that were reported by Helgerud *et al*. (2001). VO_{2max} has been used to differentiate between successful and less successful soccer teams (Hoff and Helgerud, 2003; Krustrup *et al.,* 2003; Bangsbo *et al*., 1991), elite from non-elite and professional from amateurs (Janssens *et al*., 1998). Despite the finding that there was no significant difference between the VO_{2max} of the two teams, the Zimbabwean team seem to be the better team compared to the South African team considering the higher VO_{2max} and distance covered in Hoff test.

E. Conclusion

No literature has been published to date on the functional fitness capacities of young players from South Africa and Zimbabwe. Therefore this research study is going to give the baseline significant contribution to literature on body composition and functional fitness characteristics of young soccer players in South Africa and Zimbabwe. Physical tests such as shoulder flexibility, and overhead power throw have not been widely used in the field of soccer, this study shall provide fundamental information to soccer coaches, trainers and other researchers on the relevance of these tests in soccer.

The study indicated that Zimbabwean players performed better in most tests except in left shoulder flexibility, but there were no differences in VO_{2max} of the two teams. The study found out that of all the body composition and functional fitness variables assessed, the most discriminatory ones were; %BF, fat mass, agility, speed and power. Height and weight are important on allocating positional roles, but cannot discriminate successful from less successful performers. Therefore it was concluded that agility, speed and power variables are the most important variable in talent selection.

Basing on group means for the observed distinguishing variables (agility, power and sprints) the finding showed that more Zimbabweans have future potential of success in soccer. The predictions are shown below (Table 7.6). Those with possibility for success have scores above the group mean and those with less potential for success scored below the group mean.

Table 7.6: Comparison of players with future potential for success in soccer and those with less potential

		South Africa		Zimbabwe	
Distinguishing variable	**Mean Score**	**Success Potential**	**Less potential**	**Success Potential**	**Less potential**
Agility	16.7 sec	**39.1%**	60.9%	**69.7%**	30.3%
10m	1.7 sec	**29.3%**	70.7%	**54.5%**	45.5%
20m	3.0 sec	**70.7**	29.3%	**81.8%**	18.2%
40m	5.5	**39.1%**	60.9%	**75.8%**	24.2%
Vertical jump	46.9	**53.6%**	46.4%	**60.6%**	39.4

When comparing the current study to other studies elsewhere, the current study has the highest speed (10, 20, and 40m) than Australian and European players, the group is less agile and also has less explosive power compared to the Europeans. Height and weight were comparable to Asians but was less compared to Australians and Europeans.

Goalkeepers and defenders were heavier, taller and had higher values of %BF and fat mass, while forwards and midfielder were leaner, shorter and lighter but faster. Goalkeepers scored better in vertical jump test because of the height advantage. This was found to be a similar trend with other teams studied elsewhere. Jumping is more important to goalkeepers and defender than to other players.

Body composition variables showed some relationships with functional fitness variables. Height, sum of skinfolds, body density, and %Bf were found to correlate with power. %BF and body density were found to correlate with agility and speed variables.

F. Future studies

Different studies have reported varying results in body composition analysis mostly due to the use of heterogeneous subjects, use of different body composition predicting equations as well as different assessment method like the BIA, DEXA, hyrodensitometry, skinfold, etc. It would be quite interesting to assess the validity of these methods by comparing two or more methods on one homogeneous group and see the extent of the differences.

G. Limitations

Purposive sample technique was used, hence the results cannot be generalised to represent all the South African and Zimbabwean junior team players.

BMI was calculated to predict adiposity of players but its main weakness is that it does not consider whether the total body mass is composed more of muscle mass or fat mass. For this reason skinfold measurements and waist:hip were also included, which gives a better understanding of muscle and fat mass.

Some players stayed together at the academy and went to the same school; they practised together both at the academy and at school while others stayed at their homes. This gave them more time to practice and an advantage over those players who stayed at their homes. Reilly *et al*., (2005) reported that experience and more practice time give young player opportunities for future success.

Aerobic capacity was assessed using a field test (Hoff test). Helgerud *et al*., (2001) Hoff, (2005) and Aziz *et al*., (2005) propound that treadmill tests are considered the gold standard for VO_{2max}, compared to field methods like the Yo-Yo test, Hoff test, or multistage shuttle test. However, laboratory tests are not feasible to administer in large groups.

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APPENDIX A: Consent form

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

Body composition and functional fitness capacity of young academy soccer players from South African and Zimbabwean.

Your child is kindly asked to participate in a research study conducted by Vincent Masocha (Bsc 'Hons' Sport Science), from the Department of Sport Science at Stellenbosch University. The results of this study will contribute to a Master's thesis in Sport Science. Your child has been selected as a possible participant in this study because he is a well-trained male academy soccer players from South Africa / Zimbabwe

1. PURPOSE OF THE STUDY

The purpose of the study is to explore distinctive anthropometric, physical and functional performance characteristics of young soccer players, which can be used to predict their future success in soccer. High magnitude of functional capacity indicators like agility, strength, flexibility, speed and power are predictors of future potential success in soccer career.

2. PROCEDURES

If he volunteers to participate in this study, we would ask him to do the following things:

During the first session he will be asked to undergo a number of body composition measurements and during the second session he will be asked to complete a series of physical fitness tests as well as soccer specific tests.

3. POTENTIAL RISKS AND DISCOMFORTS

The study does not carry any serious risk for your child. He may experience minor discomfort during the physical exercise tests. However, this will be no more than the usual discomfort he feels while training or playing a soccer match at his club.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The coaches will receive a summary of body composition analysis, as well as functional capacity test results. This is valuable information which your child as a player and his coaches may use when planning their training programs. The results of this research will contribute to science as it will give us a better understanding of the body composition, somatotype and functional capacity of soccer players from Africa as most of the studies in this context were done outside Africa.

5. PAYMENT FOR PARTICIPATION

There will be no payment for participation in this study, the participation is voluntary.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with your child will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of assigning your child a numeric code so that he is not identified by his real name. That code will be used rather than his name. Data will be kept on my computer which is password protected and will only be accessible to me and no one else.

Confidentiality with publication of results will be kept by not publishing the raw data as well as making use of the codes assigned to the participants.

7. PARTICIPATION AND WITHDRAWAL

The child can choose whether to be in this study or not. If he volunteers to be in this study, he may withdraw at any time without consequences of any kind. His withdrawal will not have any influence during team selection by his coaches. The investigator may withdraw your child from this research if circumstances arise which warrant doing so.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact

Vincent Masocha

Phone: 0842386018 / Email: 16959817@sun.ac.za

Prof E Terblanche

Phone: 021 808 2742 / Email: et2@sun.ac.za

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and the child will discontinue participation without penalty. You are not waiving any of your child's legal claims, rights or remedies because of your consent to his participation in this research study. If you have questions regarding the child's rights as a research subject, please feel free to contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to me ____________________ by Vincent Masocha in English and I am in command of this language or it was satisfactorily translated to me. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

I hereby consent voluntarily to let my child participate in this study. I have been given a copy of this form.

____

Name of Subject/Participant/Parent/Guardian

____

Name of Legal Representative (if applicable)

____ ________________

Signature of Subject/Participant or Legal Representative **Date**

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to ________________ (*parent/guardian)* and/or [his/her] representative_______________________.*[H*e/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in English and no translator was used.

____ ________________

Signature of Investigator **Date**

Appendix B: Assent form

	STELLENBOSCH UNIVERSITY

PARTICIPANT INFORMATION LEAFLET AND ASSENT FORM

TITLE OF THE RESEARCH PROJECT:

Body composition and functional fitness capacity of young academy soccer players from South Africa and Zimbabwe.

RESEARCHERS NAME(S): Vincent Masocha

ADDRESS: Department of Sport Science, Stellenbosch University

CONTACT NUMBER: +27 842386018

WHAT IS RESEARCH?

Research is something we do to find new knowledge about the way things (and people) work. We use research projects or studies to help us find out more about disease or illness. In sport, research helps us to find better ways of improving our coaching and training, or identifying talent in a specific sport.

What is this research project all about?

This research study seeks to find out how body size, body shape and physical fitness of soccer players can help us to determine whether young players can grow to become professional players in future or not. The assessments will include skinfold measurements, girths and circumferences of your limbs, as well as testing your speed, flexibility, power, strength and ability to run and change direction quickly.

Why have I been invited to take part in this research project?

You have been invited to take part in this research study because you are a well-trained under 17 soccer player at Camps Bay Football club *(this will be changed for the club in Zimbabwe)*

Who is doing the research?

The research study will be conducted by Vincent Masocha, from the Department of Sport Science at Stellenbosch University. The results of this study will contribute to a Master's thesis in Sport Science.

What will happen to me in this study?

If you volunteer to participate in this study, we would ask you to do the following things: During the first session you will be asked to undergo a number of body composition measurements and during the second session you will be asked to complete a series of physical fitness tests as well as a soccer specific test. The tests include running a distance of 40m to measure how fast you are (speed), testing the flexibility of your hamstrings and shoulders, testing your leg power and strength, as well as your ability to change direction at a fast pace.

Can anything bad happen to me?

The study does not carry any serious risk for you as participant. You may experience some discomfort during the physical exercise tests. However, the discomfort will be not more than the usual discomfort you feel while training or playing a soccer match. If you experience any pain during the tests, you should let me know immediately so that we can stop the test.

Can anything good happen to me?

Your coaches will receive a summary of your body composition analysis, as well as functional capacity test results. This is valuable information which you or your coaches may use when planning your training program. The results of this research will contribute to science as it will give us a better understanding of the young soccer players from Africa as most of the studies in this context were done outside of Africa.

Will anyone know I am in the study?

No person shall know you by your name in the study. You will be given a numeric code to identify you in the research study. Your real name will not be included in the research write up and only group results will be published and not individual results or raw data.

Who can I talk to about the study?

If you have questions regarding your rights as a research subject, please feel free to contact Professor E Terblanche. Phone: 021 808 2742 / Email: et2@sun.ac.za, at the Department of Sports Science, or contact Ms Maléne Fouché [mfouche@sun.ac.za / Phone 021 808 4622] at the Division for Research Development

What if I do not want to do this?

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without punishment of any kind. Your withdrawal will not have any effect on your chances to be selected for the team for soccer matches. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

Do you understand this research study and are you willing to take part in it?

YES	NO

Has the researcher answered all your questions?

YES	NO

Do you understand that you can pull out of the study at any time?

YES	NO

________________________ ____________________

Signature of Child Date

	STELLENBOSCH UNIVERSITY

APPENDIX C: Demographic questionnaire

Demographic Questionnaire.

Body composition and functional fitness capacity of young academy soccer players in South Africa and Zimbabwe.

Dear participants;

You are kindly requested to complete this small questionnaire in your truthful sense. Your answers will be treated with maximum confidentiality.

Name... D.O.B....................................

1. At what age did you start playing competitive soccer? ....

2. How many years have you been at the academy? ....

3. What position do you play in the team? ....

4. How many years have you been playing in your current position? ....

5. Have you ever play for national team?..............................

6. If yes which level did you play? ....

7. Have you ever been called for trials with a Premier Soccer league team?

8. Have you been nursing an injury during the last 3 months?......................

9. Have you participated in a study of this nature before? ....

... END ....