Anthropometric Profile, Physical Fitness and Cognitive Functioning of Elite Zimbabwean Football Referees

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Declaration

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Summary

The aim of the study was to determine the anthropometric profile, body composition, physical fitness and executive cognitive functioning (ECF) of elite male Zimbabwean football referees.

A total of 41 male referees took part in the study (*M* age = 34.89, *SD* = 0.13 years). Their mean body mass was 70.52 ± 10.50kg, height: 175.72 ± 6.86cm, body mass index: 20.79 ± 2.79kg/m^2, waist-hip ratio: 0.83 ± 0.04, sum of six skinfolds: 65.77 ± 24.75mm, and body fat percentage: 11.97 ± 2.60%. A significant difference (p = .04) was found between the 21 referees (177.85 ± 7.32cm) and 20 assistant referees (173.50 ± 5.69cm), with the referees being taller. Their somatotype was 2.68-4.62-2.65 classifying them as balanced mesomorphs.

Their physical fitness results were as follows: modified sit and reach (28.31 ± 6.42cm), vertical jump (38.63 ± 5.63cm), one minute sit up (37.56 ± 9.46), and one minute push up (26.13 ± 6.89). Referees on the Fe´de´ration Internationale de Football Association (FIFA, n = 8) accreditation list performed significantly (p = .04) more sit ups in one minute than those on the Zimbabwe Football Association (ZIFA, n = 33) list (36.09 ± 9.26). They recorded a best time of 5.45 ± 0.22s and a mean time of 5.62 ± 0.19s in the 6 x 40 m repeated sprint ability (RSA) test, with the FIFA referees (5.34 ± 0.25s) performing significantly better (p = .03) than the ZIFA referees (5.52 ± 0.20s).

The participants (n = 38) completed the Modified Stroop task before and after a maximal effort on the change of direction ability (CODA) and Yo Yo intermittent recovery (YYIR) level one test to determine their ECF and the effect of strenuous physical activity on their ECF. Mean time to complete the CODA test was 9.60 ± 0.42s. They covered a distance of 950 ± 279m during the YYIR test, yielding a VO_{2max} of 44.38 ± 2.35ml/min/kg^{-1}, reaching a maximum heart rate of 189.66 ± 8.61 beats per minute or 101.26 ± 4.04% of their age predicted HR_{max}. Their ECF improved from pre to post-test as follows: C_1 (12.73 ± 13.51%, p = .01) C_2 (5.48 ± 8.20%, p = .01), C_3 (9.15 ± 15.20%, p = .04), and C_4 (8.42 ± 18.01%, p = .06). Significant negative correlations of moderate strength were found between the standardised physical performance score and the Modified Stroop test results for $C_{1\ \text{pre-test}}$ (r = -0.40, p = .01), $C_{3\ \text{pre-test}}$ (r = -0.34, p = .04), as well as for all four of the conditions at post-

testing ($C_{1:}$ r = -0.35, p = .03; $C_{2:}$ r = -0.36, p = .03; $C_{3:}$ r = -0.32, p = .05; $C_{4:}$ r = -0.35, p = .03). These results indicate a significant relationship between physical fitness and ECF.

This study lays the foundation for the development of scientific training programmes for elite Zimbabwean referees, as it highlighted strengths and weaknesses. The effectiveness of such programmes is subject to further investigation.

Opsomming

Die doel van die studie was om die antropometriese profiel, liggaamsamestelling, fisiese fiksheid en uitvoerende kognitiewe funksionering (UKF) van elite manlike Zimbabwiese sokkerskeidsregters te bepaal.

ʼn Totaal van 41 manlike skeidsregters (gemiddelde ouderdom = 34.89 ± 0.13 jaar) het aan die studie deelgeneem. Hul liggaamsmassa was 70.52 ± 10.50kg, lengte: 175.72 ± 6.86cm, liggaamsmassa indeks: 20.79 ± 2.79kg/m^2, maag-tot-heup verhouding: 0.83 ± 0.04, som van ses velvoue: 65.77 ± 24.75mm, en persentasie liggaamsvet: 11.97 ± 2.60%. ʼn Betekenisvolle verskil (p = .04) is waargeneem met die skeidsregters wat langer (177.85 ± 7.32 cm) as die assistent skeidsregters was (173.50 ± 5.69 cm). Hul somatotipe was 2.68-4.62-2.65 wat hul as gebalanseerde mesomorwe klassifiseer.

Die fisieke fiksheid resultate was: gemodifiseerde sit-en-reik- (28.31 ± 6.42cm), vertikale sprong- (38.63 ± 5.63cm), een-minuut opsit- (37.56 ± 9.46), en een-minuut opstoottoets (26.13 ± 6.89). Skeidsregters op die Internasionale Sokker Federasie (FIFA) se skeidsregterspaneel kon betekenisvol (p = .04) meer opsitte voltooi (43.63 ± 8.18) as diegene op die Zimbabwiese Sokker Federasie (ZIFA) se skeidsregterspaneel (36.09 ± 9.26). Hul het ʼn beste tyd van 5.45 ± 0.22s en ʼn gemiddelde tyd van 5.62 ± 0.19s in die 6 x 40m herhaalde naelloop (RSA) toets behaal, met die FIFA skeidsregters (5.34 ± 0.25s) wat beter presteer het as die ZIFA skeidsregters (5.52 ± 0.20s).

Die deelnemers (n = 38) het ook die gemodifiseerde Stroop toets voor en na afloop van ʼn maksimale poging op die verandering van rigting (CODA) en Yo-Yo onderbroke herstel (YYIR) toetse voltooi ten einde hul UKF en die invloed van veeleisende fisieke aktiwiteit daarop te bepaal. Hul het gemiddeld 9.60 ± 0.42s geneem om die CODA toets te voltooi. Hul het ʼn gemiddelde afstand van 950 ± 279m afgelê tydens die YYIR toets, waartydens ʼn VO_{2maks} van 44.38 ± 2.35ml/min/kg^{-1} behaal is, teen ‘n gemiddelde HT_{maks} van 189.66 ± 8.61 slae/ minuut of 101.26 ± 4.04% van hul ouderdom geskatte HT_{maks}. Hul UKF het van voor-tot natoets soos volg verbeter: ($K_{1:}$ 12.73 ± 13.51%, p = .01; $K_{2:}$ 5.48 ± 8.20%, p = .01; $K_{3:}$ 9.15 ± 15.20%, p = .04; $K_{4:}$ 8.42 ± 18.01%, p = .06). Betekenisvolle negatiewe korrelasies van matige omvang is gevind tussen die gestandaardiseerde fisiese prestasietelling en die tyd vir voltooiing van die Stroop-toets gedurende voortoetsing ($K_{1:}$ r = -0.40, p = .01; $K_{3:}$ r = -

0.34, $p = .04$), asook vir al vier kondisies gedurende na-toetsing ($K_{1:}$ $r = -0.35$, $p = .03$; $K_{2:}$ $r = -0.36$, $p = .03$; $K_{3:}$ $r = -0.32$, $p = .05$; $K_{4:}$ $r = -0.35$, $p = .03$). Hierdie resultate dui op 'n betekenisvolle verwantskap tussen fisiese fiksheid en UKF.

Die studie dien as vertrekpunt vir die ontwikkeling van gestruktureerde en wetenskaplik gefundeerde oefenprogramme vir elite Zimbabwiese skeidsregters, aangesien dit sekere sterkpunte en leemtes uitgewys het. Die effektiwiteit van sodanige programme is onderworpe aan verdere ondersoeke.

List of abbreviations and acronyms

%	Percentage
*	Statistical significant difference ($p \leq .05$)
**	Statistical significant difference ($p \leq .01$)
<	Smaller than
>	Greater than
a	Moderate practical significant difference (d more or less 0.5)
b	Large practical significant difference (d more or less 0.8)
b/min	Beats per minute
cm	Centimetre
ES	Effect Size
kg	Kilogram
$kg \cdot m^2$	Kilogram per meter squared
m	Meters
ml	Millilitres
$ml/kg/min^{-1}$	Millilitre of oxygen per kilogram of body mass per minute
n	Number
s	Seconds
Σ	Sum of
ACSM	American College of Sports Medicine
BF	Body fat
BMI	Body mass index
C_1	Condition 1 - Word naming (Stroop-Word)
C_2	Condition 2 - Colour naming (Stroop-Colour)
C_3	Condition 3 - Colour and word naming (Stroop-Interference)

C_4	Condition 4 - Mixed colour and word naming (Stroop-Switching)
CODA	Change of direction ability
FIFA	Fe´de´ration Internationale de Football Association
HR_{max}	Maximum heart rate
HWR	Height to weight ratio
ICC	Intraclass correlation coefficient
ISAK	International Society for the Advancement of Kinanthropometry
M	Mean
N	Total number
PFP	Physical fitness performance score
PSL	Premier Soccer League
RSA	Repeated sprint ability
SD	Standard deviation
SKF	Skinfold
TEM	Technical error of measurement
VJ	Vertical jump
VO_{2max}	Maximal oxygen uptake
WHO	World Health Organisation
WHR	Waist to hip ratio
YYIR	Yo Yo Intermittent Recovery test
ZIFA	Zimbabwe Football Association

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Chapter 1
Problem Statement and Aims

Introduction

Referees play a crucial role in football; they are responsible for ensuring that the game is played according to the rules and within the spirit of the game (Reilly & Gregson, 2006). For this reason, there is a great need to identify, train and support young referees who show potential. The on-field performance of referees depends highly on their physical, technical and mental qualities (Weston *et al*., 2012). They have to be well-trained and monitored on a regular basis, because the physical demands placed on them are similar to those of football players (Weston *et al*., 2004).

The Fe´de´ration Internationale de Football Association (FIFA) introduced physical fitness test batteries in 1989 as a strategy to improve the quality of officiating at the different levels of the game (Rontoyannis *et al*., 1998, Cerqueira *et al*., 2011). Several studies have been carried out in different countries during top level competitions to evaluate the performance, physical fitness, anthropometric, morphological and medical profile of elite football referees. Mallo *et al*. (2007; 2009) conducted research on elite FIFA referees during the 2005 Confederations Cup, whereas studies have also been conducted in Greece (Rontoyannis *et al*., 1998), England (Weston *et al*., 2004; 2006; 2007; 2010; 2011a; 2011b; 2012; Reilly & Gregson, 2006; Catterall *et al*., 1993), Spain (Caballero *et al*., 2011), Brazil (Da Silva *et al*., 2008; 2011; D'Ottavio & Castagna, 2001), Denmark (Krustrup & Bangsbo, 2001; 2007; Bangsbo *et al*., 2003; 2006), the United States of America (Barbero-Alvarez *et al*., 2012), Italy (Castagna & Abt, 2003; 2005a; Castagna *et al*., 2005b) and South Africa (Lategan, 2011). These studies have been useful in understanding, developing and improving the performance of football referees. Furthermore, findings from these studies have prompted and influenced the design and implementation of training programmes aimed at helping football referees achieve an appropriate level of match fitness (Castagna *et al*., 2004).

Testing in sport is important as it can be used to monitor athletes' performance and their response to training prescriptions (Bangsbo *et al*., 2006). Testing occurs at both the group and individual level, which allows for researchers to understand the athletes' performances by sport, playing position and individually. Similarly, the testing of referees is important to obtain information about their physical and physiological capabilities and body composition

(Caballero *et al*., 2011; Da Silva *et al*., 2011), as well as to use their test results for selection and classification purposes (Weston *et al*., 2012). In recruiting, training and developing referees, profiling has been widely used. Profiling of referees is of importance to the referees themselves, but also to physical fitness instructors and those working with the referees at the different levels (Weston *et al*., 2009; Weston *et al.,* 2011a). It allows for the functional evaluation and continuous monitoring of refereeing activities and assessing the benefits or responses to prescribed training programmes or workloads. The profiling of referees can be a useful tool in their professional careers by monitoring and improving their performance (Caballero *et al*., 2011).

Because FIFA wants the best referees to officiate at elite competitions and games, they have recommended that referees should be healthy and in good physical condition, have sound technical and psychological skills and a high level of education. There are FIFA regulations governing the registration of international referees by member associations to the FIFA international referees' list (FIFA, 2010). For instance, referees must be younger than 35 years to register for the first time and not older than 45 years to be registered on the FIFA international referees list. These referees should have officiated regularly during matches at the highest division of their respective countries for at least two years and have passed the category one FIFA physical fitness test. Refereeing experience is also important to officiate at high profile national and international matches (Eissmann *et al*., cited by Castagna *et al*., 2005a). The FIFA Referees Committee decides on the maximum number of referees from each country that may register each year, based on the levels of the competitions and refereeing in each country.

Body composition and anthropometric variables are useful tools for monitoring changes taking place in the referees' morphology as a result of training or physical demands of the game (Da Silva *et al*., 2011). The mean height and body mass of FIFA elite referees during the 2005 Confederations Cup was 183 ± 0.04 cm and 78 ± 4.49 kg (Mallo *et al*., 2009). Krustrup *et al*. (2009) reported a mean body mass index of 23 kg/m^2 (range: 20 to 27 kg/m^2) among elite European FIFA referees (n = 15) and 24 kg/m^2 (range: 22 to 28 kg/m^2) among elite FIFA assistant referees (n = 15). Da Silva *et al*. (2011) reported that Brazilian national referees (n = 215) had a percentage body fat of 19.3 ± 4.1 %, which they concluded was higher than that of football players.

The 2010 FIFA World Cup South Africa technical report and statistics reported that the mean age of football players was 27 ± 1.17 years, whilst the mean age of the referees were 39 ± 3.60 years (FIFA, 2011). Despite the age difference, these referees are expected to keep up with the pace of the game and be within the optimum distance of between 10 to 15 meters from the play or the point of infringement in order to make the correct decisions.

Football involves high intensity and intermittent exercise bouts, with a change in the activity or the pace thereof every four to six seconds (Bangsbo, 1994). Referees, therefore, require high fitness levels (D'Ottavio & Castagna, 2001). Kruger *et al*. (2012) reported that physical fitness concerns were the leading stressor experienced by South African soccer referees. Heart rate recordings during matches are useful to classify the intensity of activities as it has been shown to correlate with the distance covered by the referees on the field (Mallo *et al*., 2009). Caballero *et al*. (2011) pointed out that the best indicators of physical performance during the game were the amount of high intensity running that referees perform. The level of exertion during the 2005 FIFA Confederations Cup for FIFA referees was 86 ± 3% HR_{max} and for assistant referees 78 ± 4 % HR_{max} (Mallo *et al*., 2007; Mallo *et al*., 2009). Caballero *et al*. (2011) reported a mean VO_{2max} of 48.0 ± 4.3 $ml/kg/min^{-1}$ among 22 Spanish referees (mean age: 26.2 ± 5.0 years), whilst Castagna *et al*. (2005a) reported a higher mean of 52.1 ± 7.36 $ml/kg/min^{-1}$ among eight elite Italian referees (mean age: 33.1 ± 1.8 years). These studies show that referee's cardio-respiratory fitness levels are high compared to sedentary people of their age according to ACSM (2012) norms.

Tomporowski and Ellis (1986) showed that fit individuals performed better in cognitive tasks after exercise than their unfit counterparts. Tomporowski (2003) also concluded that submaximal aerobic exercise bouts lasting up to 60 minutes had a positive contribution on the cognitive function of physically fit participants, but exercise bouts that lasted longer than 60 minutes usually affected cognitive functioning negatively. Weinberg and Gould (2011) emphasised the need to simultaneously develop psychological and physical functions to ensure consistent performances. Because of the high physical demands of the game, it has been observed that referees tend to fatigue during the second half, resulting in them being further away from infringements (Krustrup & Bangsbo, 2001; Weston *et al*., 2006; Mallo *et al*., 2009). However, it is uncertain whether the decline in the physical performance of the referees has any effect on their cognitive functioning and the quality of decisions they tend to make during games (Reilly & Gregson, 2006).

Given the strenuous physical demands of officiating matches, it is surprising that little attention have been directed at assessing the mental and psychological skills of referees. Referees are expected to remain consistent in their decisions in the face of distractions from the crowd and pressure from coaches and players, the economic importance of the game and the temptation of remuneration from interested parties (Nevill *et al*., 2002; MacMahon *et al*., 2007; Catteeuw *et al*., 2009; Karademir, 2012). Furthermore, decisions made during the game could have a direct influence on the match results (Bangsbo 1994; Caballero *et al*., 2011) and could have far reaching consequences for the teams and players. In an effort to optimize the decisions that referees make during the game, FIFA has introduced video training material for referees (Helsen & Bultynck, 2004). Helsen and Bultynck (2004) calculated that an elite football referee makes an average of 137 observable decisions per match and that referees may encounter three to four situations per minute that may require them to make decisions. Johnson (2006) noted that decisions made in sport settings are dynamic, made under pressure and are spontaneously encountered. A good knowledge of the rules of the game alone is not enough for a referee to successfully officiate a game. The ability to shift attention from broad to narrow and vice versa depending on the dynamics of the game, as well as the ability to inhibit any external influences is essential prerequisites in officiating. Furthermore, the inability to properly control attention could induce stress thereby affecting mental fatigue (Warm *et al*., 2008; Moore *et al*., 2012).

In order to develop elite referees that will have a chance of being selected to officiate at top level competitions, it is important to embrace the valuable findings from research studies. Reilly and Gregson (2006), as well as Weston *et al*. (2012) have emphasised the need for more studies to focus on identifying the important systems that support the decision making process of referees so as to enhance their decision making skills. Such findings prompt for more research to find answers on how decision making and cognitive functioning of referees can be improved in the face of prolonged exercise and varied internal and external pressures associated with officiating matches.

Aim of the study

The aim of the study was to determine the anthropometric profile, physical and cognitive function of elite male Zimbabwean Premier League football referees.

Specific aims of the study

- To determine the anthropometric characteristics of these referees.

- To determine the physical fitness levels of these referees.
- To compare the anthropometric and physical fitness characteristics of FIFA and Zimbabwean Football Association (ZIFA) referees.
- To compare the anthropometric and physical fitness characteristics of referees and assistant referees.
- To compare the cognitive function of the referees before and after a fatigue-inducing protocol to determine the influence of fatigue on reaction time and decision-making.
- To describe the relationship between cognitive function and physical fitness of these referees.

Assumptions

It was assumed that all the referees gave their best effort during the physical testing and were not involved in any vigorous training or physical activities in the 24 hour period prior to testing (as instructed). It was assumed that the participants followed the prescribed weekly training programme from the national physical fitness instructor. Furthermore, it was also assumed that all the participants understood the Stroop cognitive function test after they were familiarised with the test.

Delimitations

The study was limited to men that have officiated and are registered FIFA or ZIFA Premier League referees from Zimbabwe.

Limitations

The sample of convenience lacks representation of all referees in Zimbabwe. The results of this study is, therefore, only a good representation of elite referees from Zimbabwe that were on the 2013 FIFA international or ZIFA refereeing panel and were officiating in the Zimbabwean Premier league. Therefore, the generalisation of results to referees in the rest of the world or from other levels of refereeing is cautioned.

Motivation and potential benefits

Like many other FIFA member countries, Zimbabwe contributes a number of referees to the FIFA international referee’s list. However, there are only a few Zimbabwean referees that have officiated in big tournaments like the Olympics, Confederations Cup and Africa Cup of Nations, whilst only one referee has managed to officiate at the World Cup. Concerns have been raised why Zimbabwean referees have not been able to officiate at elite competitions.

To the best knowledge of the author no previous studies has been conducted to profile elite Zimbabwean referees which can be used to lay the foundation for developing these referees. There is subsequently a need to gather information regarding the elite Zimbabwean referees' morphology, physical ability and cognitive functioning. This knowledge could be used to improve their performance as it would enable fitness trainers to develop specific training programmes using the knowledge gained from this study. Furthermore, the information will be useful in the process of developing a career programme for identified talented young referees in Zimbabwe.

Chapter 2
Literature Study

Introduction

The game of football is competitive, tactical and scientific and has attracted large numbers of spectators and sponsors. As a result players and coaches are put under immense pressure to win games for financial gains and to maintain team pride. All these factors add to the pressure on the referees officiating football games. In an effort to improve the performance of referees, refereeing has become a professional career in developed countries (Weston *et al*., 2010). Full time, professional referees have enough time dedicated to training and development of their refereeing careers, compared to when a referees' training programme and officiating duties are scheduled around work and family commitments. From 2000 to 2006 the number of practising referees increased from 720 000 to 840 000 (FIFA, 2000; FIFA, 2007). This increase in numbers shows that more people around the world are choosing refereeing as a career. This has prompted the football governing body to train referees that will uniformly apply and interpret the laws of the game, as well as meet the mental and physical demands of the game, even when under pressure from coaches, players, spectators and their assessors.

Referees are athletes in their own right and tend to be passionate about the game and their performance (Philippe *et al*., 2009). They need to prepare technically, physically and mentally in the same way players prepare for matches or competitions. Despite the important role referees perform during football games, they have received far less attention from researchers. However, a number of studies have been conducted in recent years to enhance our understanding of the morphological, physical (Catterall *et al*., 1993; Rontoyannis *et al*., 1998; Krustrup *et al*., 2002; Castagna *et al*., 2005a; 2005b; Weston & Castagna, 2005; Mallo *et al*., 2007; Mallo *et al*., 2009; Krustrup *et al*., 2009; Weston *et al*., 2009; 2012; Caballero *et al*., 2011; Da Silva *et al*., 2011; Lategan 2011) and mental characteristics (Plessner & Betsch, 2001; Helsen & Bultynck, 2004; Plessner & Haar, 2006; MacMahon *et al*., 2007; Catteeuw *et al*., 2009; Catteeuw *et al*., 2010) of referees in order to improve their performance on the field of play and to establish talent identification criteria.

The history of football refereeing

The history of the laws of the game dates back to around 1840 when students at Cambridge University tried to draw up uniform standard of playing rules (FIFA, 2015). The first laws of the games were introduced in 1863 (Bizzini, 2010). At the time football officials were called umpires. The two opposing teams would each choose their own umpire and there would be the main umpire who would keep time and officiate from the touchline. The umpires from each team were responsible for receiving appeals from their teams and in consultation with the main umpire would make a decision. This would take a lot of time as there would be disagreements resulting in long delays before decisions were made. By 1888 there was a growing need for a neutral referee. A few years later, in 1891, the International Football Association Board introduced the referee and two linesmen as we know it today, except that linesmen are now called assistant referees (Bizzini, 2010; FIFA, 2015). The referee was allowed to officiate on the field of play, while the two linesmen officiated along the touchlines on each side of the field. The referee had overall powers to implement the laws of the game without having to consult the linesmen to make a decision (FIFA, 2015). As a result referees got more involved in the dynamic movements on the field of play while officiating; for example the referee moved in parallel, zig-zag or diagonal movement patterns in search of the most favourable position and distance from the play and infringements. Due to the high expectations placed on the referees to correctly interpret and apply the laws of the games whilst involved in dynamic intermittent movements, they need to be mentally and physically fit.

Age and physical match performance

In elite sport, referees or umpires tend to be older than players. In rugby, Rainey *et al.* (1997), as well as Kay and Gill (2004) reported an average age of 41 ± 3.4 years and 35 ± 3.9 years for referees, while basketball referees from Germany had a mean age of 33 years (Brand *et al*., 2006). In a study conducted on elite Australian basketball referees, Leicht (2007) reported that the referees were on average 29 ± 3.9 years old, with their years of experience ranging between one and fifteen years.

The 2010 FIFA World Cup South Africa technical report and statistics reported that the average age of the players was 27 ± 1.17 years, while the referees were on average 39 ± 3.60 years old. Referees in the 2013 Confederations Cup held in Brazil, were of similar age, namely 39 ± 3.50 years (FIFA, 2013b). Weston *et al.* (2010) reported that the average age difference between football players and referees ranged between 10 and 15 years. Castagna *et al*. (2005a) contends that elite referees reach their best performance and highest career level around the age of 40. Despite being older than players, referees are expected to perform at similar levels as football players and as such referees are considered to be elite performers as well (Weston *et al*., 2010). Weston *et al*. (2011b) revealed that referees covered greater mean match distances than the players during a football season (11 280 ± 738 m versus 10 794 ± 374 m; $p < .001$, effect size (ES) = 0.83) and there were strong correlations between the players' and referees' total distance covered ($r = 0.644$, $p = .003$) and high speed running time ($r = 0.624$, $p = .006$). During matches, the referees are expected to keep up with play despite the age difference between them and the players as they need to be well positioned to observe play and implement the rules of the game.

It is known that increasing age affects physical performance. Katch *et al.* (2011) stated that maximum strength in men and women is achieved between the ages of 20 to 30 years, after which strength is gradually lost. According to Bunn (2011), ageing causes the loss of fast twitch fibres and promotes an increase of slow twitch fibres, which means that older referees will tend to be slower than the average player. Furthermore, maximum cardiac output also decreases with age, mainly due to a decrease in maximum heart rate (Hawkins and Wiswell, 2003). This would cause a lower endurance capacity with ageing.

Weston *et al.* (2010) studied the effects of age on physical performance and match physiological load on younger (age ranged from 31 to 36 years) and older elite English football referees (age ranged from 43 to 48 years). They found that older referees covered a shorter distance during a game compared to the younger referees (11 302 ± 749 m vs. 12 209 ± 713 m). However, they also observed that older referees managed to keep up and were within the optimum distance from fouls during play. The authors attributed this to the fact that older referees were more economical in their movements and more able to anticipate play, thereby maintaining a similar distance to the match action than the younger referees. It can be assumed that referees' years of experience make up for the detrimental effects of ageing on physical performance.

Due to the effects of age on physical performance, FIFA first introduced the age limit of 45 years during the 1990 World Cup (Caballero *et al*., 2011). However, since the labour laws in Europe state that the retirement age is 65 years, older referees (> 45 years) have maintained that they should be allowed to officiate until the age of 65 years, as long as they are still able to complete and pass the required fitness test. This issue is particularly important in Europe where refereeing is a profession.

Refereeing experience

There are four categories of refereeing; each category corresponds to a level of football in a country. A category one referee for example officiates in the professional league or competition in a country (FIFA, 2010). In professional football leagues and competitions, the selection of referees is based on experience and ability to complete and pass the required FIFA physical fitness, medical and technical test on their knowledge of the laws of the game (Castagna *et al*., 2005a; Stølen *et al*., 2005). Catteeuw *et al*. (2009) reported that Belgian referees who officiated in the 2006 World Cup in Germany started their careers at the age of 18 ± 2.9 years and had, on average, 19 ± 4.1 years of experience. Their counterparts, the assistant referees, started their careers at the age of 19 ± 2.8 years and had experience of 15 ± 2.6 years, 4 ± 2.9 years less than the referees. The referees who officiated at the 2006 World Cup had been officiating for 5.7 ± 2.0 years at FIFA international level, whereas the assistant referees had 4.1 ± 2.7 years of experience at the same level (Catteeuw *et al*., 2009). During the 2005 Confederations Cup, the elite FIFA referees had an average of 8.05 ± 3.39 years' experience at this level (Mallo *et al*., 2009). The experience referees accumulate during their careers is of fundamental importance for success in officiating on the field of play (Weston *et al*., 2010).

Anthropometric profile and body composition

The modern game of football requires referees to be physically fit to officiate effectively in matches despite the onset of physical exhaustion. Furthermore they should not experience stress to the extent that it adversely affect their decision making ability (Da Silva & Nascimento, 2005). Rontoyannis *et al*. (1998) proposed that it was important to evaluate and assess the functional, medical and morphological profiles of referees so as to come up with means and methods to improve their performances. According to Wallace *et al*. (2009) and Moon (2013), excessive body weight has a negative effect on performance. Wilmore and Costill (2004) stated that body fatness is associated with poor performance in speed, endurance, balance and agility. The high amounts of adipose tissue and low muscle mass are considered a limiting factor of performance (Sutton *et al*., 2009). Overweight referees cover match distances with greater difficulty and at a higher energy expenditure, making it important to monitor their percentage body fat. The referee is expected to be mobile and able to carry their own body weight around the field throughout the entire match without any difficulty. The process of monitoring body composition of referees is thus important for health, nutritional guidance and to develop specific training programmes (Durnin & Womersley, 1974; Rontoyannis *et al*., 1998; Castagna *et al*., 2007; Da Silva *et al*., 2011; Moon, 2013).

Body composition

Body composition is defined as the relative amounts of fat mass and fat free mass found in the human body. It is the ratio of different components or variables that forms part of the body and includes fat, muscles, bones and the organs. On average the fat free mass of a human body consists of 73 % water, 19.4 % protein and 6.8 % minerals (Brozek, 1961; Wagner & Heyward, 2000). Fat mass includes both essential and nonessential fats. Essential fat is found in bone marrow, liver, kidneys, intestines, muscles, heart, spleen and the central nervous system. It is required for the normal functioning of the human body. According to Katch *et al*. (2011), essential fat in men is less than that found in women and consists of approximately 3% and 12% of the total body fat respectively. The nonessential fat, sometimes called the stored fat, is found in the adipose tissue (McArdle *et al*., 2010). It consists of the visceral fat which is stored around the body organs in the abdominal area and the subcutaneous fat that is found beneath the skin of the human body. Fat is an important component of the human body because it serves as an energy reserve, protects the vital organs of the body, assist in the transportation of fat soluble vitamins, provide insulation during the cold and is a hunger suppressor (Katch *et al*., 2011).

The importance of body composition measurements

Body composition measurements are useful to trace health risk factors and to monitor obesity among referees (Rontoyannis *et al*., 1998; Reilly & Gregson, 2006). Ellis *et al*. (2000) stated that the increased risk for cardiovascular diseases is linked to excessive amounts of body fat. Jackson *et al*. (2013) alluded to the fact that nutrition is a fundamental component to life, and that body composition measurements are helpful in monitoring changes brought about by good nutrition over prolonged periods. The preparedness, adequacy and appropriateness of training loads can also be assessed through the use of body composition measurements. The body composition measurements can be used to monitor, evaluate, create and optimise training programmes (Da Silva *et al*., 2011; Moon, 2013). Among football referees, the assessment of body composition has been useful in giving insight into health related status, functional evaluation and physique (Rontoyannis *et al*., 1998; Reilly & Gregson 2006; Da Silva *et al*., 2011). A nutritional plan aimed at assisting referees to maintain appropriate body fat levels, is important to support their fitness training regime. The changes in shape and body structure as a result of training, physical demand of the game, aging, diet/nutrition, or lifestyle among football referees can be tracked and analysed (Da Silva *et al*., 2011). There is a growing interest in issues related to body composition or body fatness in relation to performance and health status of referees with the aim of improving performance (Da Silva *et al*., 2011).

Models of body composition

There are field methods that can be used to estimate body composition. They are not expensive, the tests can be carried out outside the laboratory and they are easy to use or perform. These methods include the anthropometric measurements (e.g., height, weight, skinfolds, girths and bone breath), bioelectric impedance analysis (BIA) and near-infrared interference (Norgan, 2005). Different formulas and regression equations from underwater weighting or hydrostatic and the skinfold methods have been developed to calculate body composition.

Anthropometric measurements

McArdle *et al*. (2010) defines anthropometry as a "standardised technique to quantify body size, proportion and shape" (p. 726). Heyward and Wagner (2004) referred to anthropometry as "measurements of the size and proportion of the human body" (p. 67). Both definitions note that anthropometry involves the techniques to measure body shape and proportion, whilst McArdle *et al*. (2010) also makes mention of standardisation of the measuring technique. The International Society for the Advancement of Kinanthropometry (ISAK) has played an important role in standardising anthropometric measuring techniques and procedures (Norton & Olds, 1996). Anthropometric measuring techniques are non-invasive and the equipment used is affordable and portable (Eston *et al*., 1996). Anthropometric measurements have been used to determine size, shape and proportion, anthropometric indices like sagittal abdominal diameter, body mass index and waist hip ratio to identify health risk diseases (Heyward & Wagner, 2004).

Body Mass, Height, Body Mass Index and Waist-Hip Ratio

The use of height, body mass and girth are useful ways to measure and express general body composition and size. The circumferences or girths are used to measure specific segments of the body (Eston *et al*., 1996). The method is based on the rule that girths reflect fat and fat free mass, and that slenderness is related to lean body mass (Wagner & Heyward, 1999). Body mass index (BMI) and waist-hip ratio (WHR) have been widely used to identify levels of overweightness and obesity. FIFA has been using BMI as a tool to identify underweight, overweight, or obese referees. The advantage of these measurements is that they are easy to collect and calculate. BMI is calculated by dividing weight by height squared. BMI is a rough measure of body composition and is associated with relative body fat (Wilmore & Costill, 2004; Castagna *et al*., 2007; Reilly *et al*., 2009). It has also been used as a measure of obesity and energy stores (Norgan, 2005). It has also been described as a measure of the heaviness of human beings (Abernethy *et al*., 1996).

BMI has also been criticised by many authors. Reilly *et al*. (2009) stated that BMI does not factor in the structure of the individual's body but it is a weight-for-height index that is used in the general population to classify or categorise people as being underweight, normal weight, overweight or obese. The method of using BMI to identify fatness in an individual does not indicate whether the person is muscular, overweight or obese (Powers & Howley, 2007). Reilly *et al*. (2009) recommend that BMI should not be used as a way to measure adiposity among athletes. If BMI is used in sport settings, it should be used with caution. Yet, the majority of studies in the past, as well as current studies, report BMI.

Table 2.1 summarises the results on body mass, height and BMI of studies conducted on football referees around the world. Krustrup *et al*. (2009) reported a mean height of 181 cm (range 168 to 192) among FIFA referees from Demark with the assistant referees being shorter than the referees, whilst Mallo *et al*. (2009) reported a mean height of 183 ± 0.4 cm among the 2005 Confederations Cup FIFA referees. There are similarities in the BMI results of football referees reported from different studies with values mostly in the upper normal weight and overweight category on the BMI table. The World Health Organisation (1995) categorises normal weight as between 18.5 kg/m^2 and 24.9 kg/m^2. Reilly and Gregson (2006) reported a BMI value of 27.1 kg/m^2 among English referees, which is very high.

The table shows that most referees have a body mass that ranges between 70 kg and 82 kg, with the majority of studies reporting mean values above 75 kg and below 80 kg. Referees from South Africa, as reported by Lategan (2011), weighed less than the referees from other countries, whilst the assistant referees were shorter and tended to be overweight.

Table 2.1. Summary of the age, body mass, height and body mass index of football referees cited in different studies.

Study	Country, level & type	No.	Age (years)	Body Mass (kg)	Height (cm)	Body Mass Index (kg/m^2)
Rontoyannis *et al*. (1998)	Greece	188	36.3 ± 4.5	81.6 ± 7.8	177.4 ± 5.7	25.9 ± 2.1
Reilly & Gregson. (2006)	England	6	37.5 ± 4.7	89.8 ± 4.8	182 ± 5	27.1 ± 5.3
Mallo *et al*. (2007)	FIFA Referee	11	39.32 ± 3.43	78.82 ± 4.49	183 ± 0.4	-
Vargas *et al*. (2008)	Chile	11	34.54 ± 4.76	76.95 ± 5.75	174 ± 5.0	25.14 ± 1.18
Krustrup *et al*. (2009)	Denmark	15	42 (range: 32 to 45)	82.5 (range: 76.1 to 93.4)	188 (range: 176 to 191)	23 (range: 20 to 27)
Castagna *et al*. (2011)	Italian Assistant Referees	50	34 ± 2.0	75 ± 4.9	177 ± 4.9	-
Da Silva *et al*. (2011)	Brazilian	215	33.7 ± 5.7	78.5 ± 10.3	177.5 ± 6.1	24.8 ± 2.8
	National	25	37.9 ± 4.1	79.00 ± 7.9	178.6 ± 4.4	24.7 ± 2.4
	Regional	190	33.2 ± 5.7	78.5 ± 10.7	177.3 ± 6.2	24.9 ± 2.9
Lategan (2011)	South African	20	27 to 46	74.08 ± 8.76	171 ± 6.7	25.61 ± 3.86
	Referees	7	-	70.56 ± 5.7	173 ± 6.5	24.06 ± 3.08
	Assistant Referees	13	-	75.98 ± 9.7	169.4 ± 6.7	26.45 ± 4.09

Skinfolds

Skinfold callipers have been widely used to measure skinfolds and to predict body density and percentage body fat from regression equations (Norton & Olds, 1996; Reilly *et al*., 2009; Katch *et al*., 2011) There estimates are based upon the two components model, namely fat mass and fat free mass (Heyward and Wagner, 2004). To estimate the composition of different components of the body, prediction equations are required and these are derived from laboratory methods. These equations have been used to predict body density and hence body fatness using data from skinfold measures (Lukaski, 1987). Many equations have been developed over the years, with the most common and widely used equations being those by

Siri (1961), Durnin and Womersley (1974), Lohman *et al*. (1984), Eston *et al*. (2005), and Wallace *et al*. (2009). The skinfold method has been criticised due to its lack of accuracy and precision when using its data to calculate body fat, as these formulas or equations are based on the general population from which the equations were derived (Lukaski 1987). However, since skinfolds are easy and cheap to measure, several studies have assessed body composition using this method and the results are presented in Table 2.2.

Table 2.2. Summary of the percentage body fat of football referees cited in different studies using the skinfold method.

	N	Country	Mean age (years)	Percentage Body Fat
Rontoyannis *et al*. (1998) [a]	122	Greek	36.3 ± 4.5	16.7 ± 4.5 %
Casajus & Castagna. (2007) [b]	45	Spanish	35.5 ± 4.4	11.3 ± 2.15 %
	13	Older	40.4 ± 2.5	11.9 ± 0.60 %
	17	Average	35.8 ± 1.5	11.1 ± 0.53 %
	15	Younger	30.4 ± 1.5	11.1 ± 0.56 %
Da Silva *et al*. (2011) [c]	215	Brazilian	33.7	18.5 %
Lategan (2011) [b]	20	South African	Range: 27 - 46	12.63 ± 4.2 %

These studies employed the following formulas:

a Slogan's equation (1962): Body Density (BD) (g/ml) = 1.1043 - (0.001327 x thigh skinfold (mm)) - (0.00131 x subscapular skinfold (mm))
  %BF= $\frac{495}{BD} - 450$

b Carter's equation (1982) (cited by Casajus and Castagna, 2007).

c. Jackson and Pollock's (1978) equation: BD = 1.112 - (0.00043499 x sum of skinfolds) + (0.00000055 x square of the sum of skinfold sites(mm) (chest, triceps, axilla, subscapular, abdominal, suprailiac and thigh)) - (0.00028826 x age)
  %BF= $\frac{495}{BD} - 450$

Somatotype

Apart from using skinfold measures to predict percentage body fat, these measures are also used to calculate a person's somatotype (Jackson *et al*., 2013). Duquet and Carter, (1996) defined somatotype as a method of describing the human physique in terms of body composition and shape. Carter, (1996), as well as Carter and Heath (1990) described somatotype as a method of quantifying the shape of the human body. Marfell-Jones (2006) described it as a process of classifying the shape of a human body without considering body size.

There are several ways of determining anthropometric somatotypes. The Heath and Carter method (Carter & Heath, 1990) is commonly and popularly used to determine somatotype that include the use of computerised somatotype software, somatotype rating forms and the use of equations. In the Heather and Carter somatotype method body composition is expressed as a three number value that represents endomorphy (the relative fatness), mesomorphy (the relative muscular skeletal development) and ectomorphy (the relative slimness or linearity) (Carter & Heath, 1990; Carter, (1996). There are 13 somatotype categories (see Table 2.3) which are based on the areas of the 2-D somatochart (Carter & Heath, 1990). These categories are illustrated in Figure 2.1. Only a few of the studies on football referees reported the somatotype results and these are summarised in Table 2.4.

Table 2.3. The 13 somatotype categories.

1	Endomorph-ectomorph	8	Ectomorphic mesomorph
2	Ectomorphic endomorph	9	Mesomorph-ectomorph
3	Balanced endomorph	10	Mesomorphic ectomorph
4	Mesomorphic endomorph	11	Balanced ectomorph
5	Mesomorph-endomorph	12	Endomorphic ectomorph
6	Endomorphic mesomorph	13	Central
7	Balanced mesomorph		

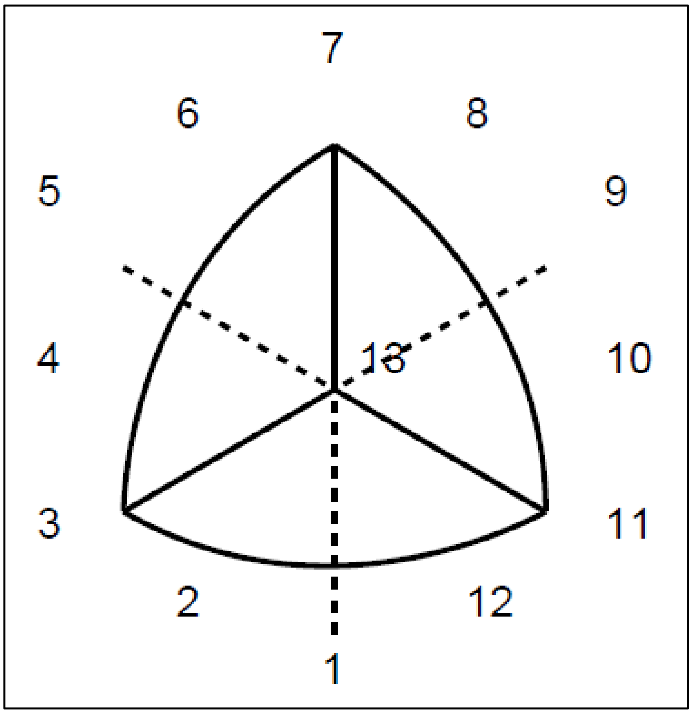


Figure 2.1. Graphic illustration of the 13 somatotype categories

Table 2.4. Summary of the somatotype results for football referees and assistant referees cited in different studies.

Author	Country, level & referee type	N	Age	Endomorph	Mesomorph	Ectomorph
Vargas *et al*. (2008)	Chile	11	34.54 ±4.7	3.81	5.67	1.57
Da Silva *et al*. (2011)	Brazil	215	33.7± 5.7	3.9	4.3	1.9
	National	25	37.9 ± 4.0	3.8	3.9	1.9
	Regional	190	33.2 ± 5.7	3.8	4.4	1.8
Lategan (2011)	South Africa	18	27 to 46	4.3	4.3	1.7
	Referees	6		4.17 ± 2.06	3.60 ± 1.34	2.13 ± 1.30
	Assistant Referees	12		4.31 ± 1.85	4.62 ± 0.93	1.44 ± 1.23

Vargas *et al*.'s (2008) study among elite referees from Chile revealed an endomorphic-mesomorph somatotype (3.81-5.67-1.57). These referees had a greater musculo-skeletal component compared to the referees from the other countries. Da Silva *et al*. (2011) reported that Brazilian referees (n = 215) were mesomorphic-endomorphs with a mean of 3.9-4.3-1.9, with the regional level referees (n = 190) reporting a higher mesomorphic score (3.8-4.4-1.8) than the 25 national level referees (3.9-3.9-1.9). The South African officials (n = 18) in Lategan's (2011) study were balanced meso-endomorphs (4.3-4.3-2.13), with slight differences between the referees (4.7-3.9-1.8) and assistant referees (4.3-4.6-1.4).

Body composition and age

Da Silva *et al*. (2011) asserted that most changes taking place in the referees' morphology were due to an increase in fat mass with aging. Casajus and Castagna (2007) stated in their discussion that the appropriate body composition may contribute to maintenance of aerobic fitness in older referees. Therefore, the importance of monitoring body composition among referees is critical. In a brief review, Reilly and Gregson (2006) reported that English referees (mean age 37.5 ± 4.7 years) had a higher percentage body fat than the players (mean age 26.3 ± 5.0 years) in the same league. The football officials had a percentage body fat of 18.9 ± 3.7 %, compared to the 13.0 ± 2.0 % of the players. Furthermore, they commented that the percentage body fat values of the referees were normal for their age.

Earlier, Castagna *et al*. (2005a) reported that there was no significant difference among Italian younger and older referees in terms of their height, body mass and percentage body fat, but that the older referees' performances in physical fitness tests, like the 50 m sprint and 12 min run test was poor. In another study Castagna *et al*. (2005b) reported that top level referees (n = 14, mean age 37.5 ± 4.5 years) from Italy had a body mass of 78.5 ± 5.6 kg which was heavier than low level referees (n = 14, mean age 24.8 ± 1.2 years) who had a mean body mass of 77.6 ± 3.6 kg. Although the sample sizes were small, these studies demonstrated that older referees were heavier than the younger referees.

Body composition and physical exercise

Casajus and Castagna (2007) reported that the younger and older referees in their study had similar anthropometrical measurements. The older referees managed to maintain their aerobic fitness which the authors attributed to maintaining appropriate body composition values. Therefore, low body fat percentages are desirable for performance. Despite the fact that there is no standard required or recommended acceptable body size or composition, referees are expected to develop appropriate physique and physical capacity to be able to meet the requirements of the FIFA physical fitness test to be able to officiate at elite level (Helsen and Bultynck, 2004; Reilly and Gregson, 2006; Castagna *et al*., 2007; Weston *et al*., 2012).

Physical ability and fitness

The intermittent nature of football and the physical demands on referees

A football game lasts at least 90 minutes and involves aerobic and anaerobic episodes of different durations for both players and referees (Bangsbo *et al*., 2008). The intermittent nature of football is described as prolonged exercise with alternating intensities of high intensity movements like running, cruising, sprinting and cutting, as well as lower intensity movements like forwards and backwards jogging, walking, shuffling and standing (Bangsbo & Lindquist, 1992; Orendurff *et al*., 2010). These movements take place spontaneously at different durations and intensities during a football match. Bangsbo (1994) observed that there is a change in activity or pace every four to six seconds during a game. Through motion analysis, Krustrup and Bangsbo, (2001) reported that referees performed a total of 1268 (range 965 to 1577) activities during a match and on average changed activities every 4.3 s. Krustrup *et al*. (2002) also assessed the movement patterns of assistant referees and reported that they executed 1053 (range 832 to 1459) activities that changed every 5.0 s.

Referees are required to move among players in an attempt to get into the best position to monitor play, whilst they need to avoid interfering with play, touching the ball and obstructing the players. Their main responsibility is to enforce and implement the laws of the game, whilst the two assistant referees need to notice off-side play by taking up position in line with the last defender or the ball (FIFA, 2013a). Assistant referees find themselves facing the pitch while involved in movements like running, sudden changes of direction such as changing from forwards running or sprinting to sideways movements (Castagna *et al*., 2011). To perform these activities well referees are expected to be physically fit. The physical demands of refereeing matches have been best described through reporting the distance covered during a game, the referees' heart rates, as well as analysing the different movements that the referee is performing during the game (or intensities thereof).

FIFA physical fitness tests for referees

In response to increasing levels of competition during the 1980's (Rontoyannis *et al*., 1998), FIFA introduced a compulsory health check and physical fitness tests for referees and in 1989, referees needed to pass the physical fitness test before they could be included on the international referees' list (Reilly & Gregson, 2006). Previously, the selection of referees would be based solely on observing referees during matches. The fitness tests were introduced in an effort to improve the performances of referees. However, this has been challenging as these fitness tests need to relate to the activities performed during the game.

FIFA proposed that referees had to complete a physical test that included: 4 x 10 m shuttle runs in less than 11.5 s, 2 x 50 m's with each run in less than 7 s, 2 x 200 m's with each run in less than 32 s and a minimum of 2700 m in 12 min (Rontoyannis *et al*., 1998). During the 2005 FIFA Confederation Cup, FIFA introduced a new battery of tests (Mallo *et al*., 2007), which are still in use today. The tests should be performed on a 400 m athletics track. It consists of 6 x 40 m repeated sprints (interspersed with 90 s recovery), each completed in less than 6 s for FIFA and national level assistant referees and less than 6.2 s for FIFA and national level referees. Following the repeated sprints, the referees are given six to eight minutes rest, after which they have to complete 20 x 150 m high intensity runs. The maximal time allowed for each run is 30 s for category one referees and assistant referees, interspersed by a 50 m recovery walk in 35 s for referees and 40 s for assistant referees (FIFA, 2010). In order to pass the test, the referees have to complete a total distance of 4000 m (20 x 150 m high intensity runs and 20 x 50 m walks) faster than the imposed time limit for each run and walk.

Performance analysis

Analysing the movement patterns of players and referees has become a useful tool in defining the physical demands and the nature of activities that are typical of the game. The need for success has led coaches and physical fitness trainers to use performance analysis of matches and search for ways to understand the weaknesses in the performances of players and how to affect improvement. The same principle would apply to referees.

Several studies have been conducted to evaluate the performances, movement patterns and physical match demands of football referees (Reilly & Thomas, 1976; Krustrup & Bangsbo, 2001; Weston *et al.,* 2007; Weston *et al*., 2011b). This has been possible through the use of match analysis and time motion analyses. One of the first studies was conducted by Asami *et al*. (1988), in which hand notational analysis was used to calculate the distance covered by football referees. These referees covered a mean distance of about 10 km (range 8 to 11 km).

Reilly and Gilbourne (2003) described notational analysis as the recording of events during an activity for the purpose of gathering statistical details of the performance. In recent years, computerised notational analysis equipment has been developed to analyse movements on the field of play. The activities of the referee are recorded for the duration of the game, including the number of occurrences of activities, as well as the duration, the distance covered, and the speed of each activity. The data attained from this process allows for quantitative and qualitative feedback about the performance, activities and physical demands of players and referees. It is important that feedback on match performance is analysed objectively, accurately and with pertinence so that the fitness instructors can make informed decisions and suitable training prescription. Today there are many motion and time analysis technologies that make use of video analysis and computer technology to analyse and track referee and player movement on the field of play (Hughes & Bartlett, 2008). This has enabled fitness trainers to design training programmes that mimic the match intensity and activities in order to improve the performances of players or referees (Haines, 2013). Without such feedback from match and time motion analysis it will be difficult to understand the physical demands imposed on players and referees.

The overall distance covered by players and referees can be used to determine the exercise intensity of the game. Through motion analysis all the actions of an individual can be categorised in terms of intensity, duration, distance and frequency (Reilly & Gilbourne, 2003). Studies have shown that football referees cover a distance of 10 to 12 km during elite and international level matches, with 4 to 18 % of the total distance covered being run at speeds between 13 and 15 km/h (Bangsbo *et al*., 2006; Castagna *et al*., 2007; Weston *et al*., 2009). The distance covered and the physical stress imposed on referees has been found to resemble that of midfield football players (Stølen *et al*., 2005). On the other hand, assistant referees have been reported to cover an average distance of 6 to 8 km per match, of which approximately 1.2 km consists of lateral running (Krustrup *et al*., 2002).

Mallo *et al.* (2009) analysed 11 elite FIFA international referees during the 2005 FIFA Confederations Cup and compared the results with the 2003 U17 World Championship. They reported that referees during the Confederations Cup covered a distance of 10.2 ± 6.43 km, of which 1.92 ± 4.0 km consisted of high speed running. On average the referees were 16.3 ± 7.4 m away from infringements. In comparison, the 2003 U17 World Championship referees covered a distance of 11.1 ± 9.35 km, which included 1.41 ± 4.53 km of high speed running. These referees were on average 14 ± 6 m away from the infringements. The authors concluded that the referees performed a significant amount of high speed running (mean 8.9 ± 1.2 %) and sprinting (mean 7.7 ± 1.5 %) during high profiled matches and that this was a reflection of the level of competition.

Krustrup *et al.* (2009) reported that FIFA referees (n = 14) from Denmark ran at high speeds for 2.1 ± 0.9 % of the total time during matches (51 ± 19 occurrences), whilst the assistant referees (n = 14) ran at high speeds for 1.2 ± 0.3 % of the time (38 ± 10 occurrences). Although the assistant referees performed less high speed running than the referees, they actually performed more sprints (17 ± 5) than the referees (13 ± 4). Furthermore, the mean distance of the sprints of the referees and assistant referees was 12 m and 14 m, respectively. They also observed a significant inverse correlation between the total distance covered during a match and the distance from infringements during both the first (r = -.60) and second half (r = -.58) among these referees during international matches. The authors concluded that the referees who performed more high intensity activities tended to be closer to the infringements.

Figure 2.2 contains a breakdown of the time spent on different activities by top-class Danish referees, compiled from the data reported by Krustrup and Bangsbo (2001).

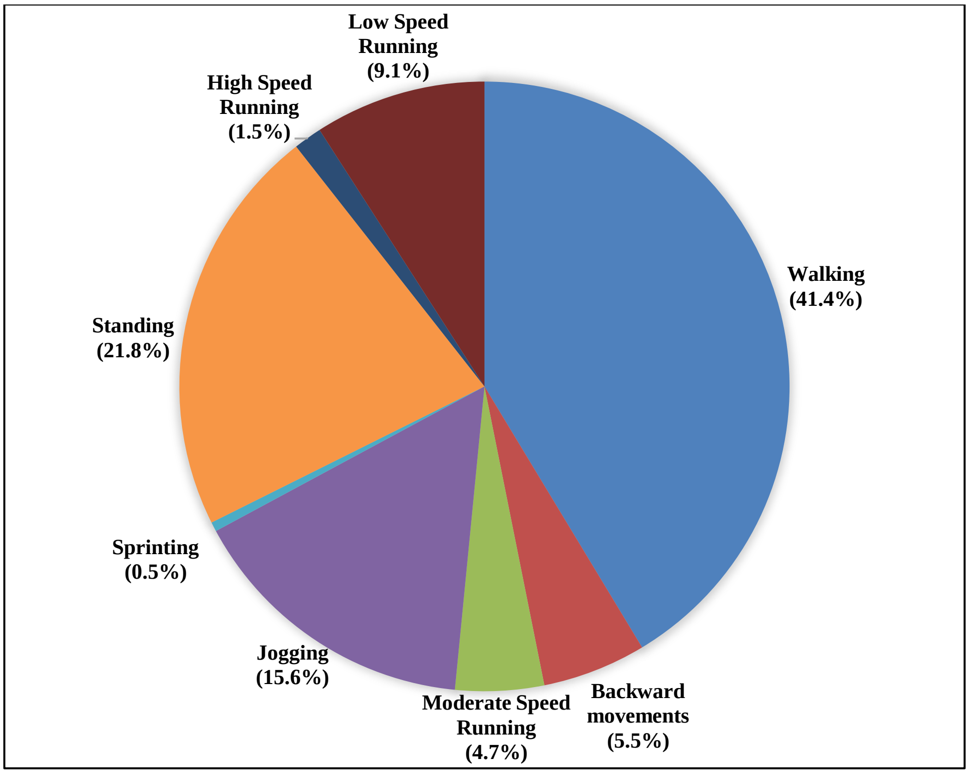


Figure 2.2. Diagram indicating the percentage of the total time spent on each type of activity by top-class Danish referees (Compiled using data from Krustrup and Bangsbo, 2001)

Several studies reported a drop in the number of high intensity runs and sprints during the second half of the game compared to the first half (D'Ottavio & Castagna, 2001; Weston *et al*., 2007; Krustrup *et al*., 2009; Mallo *et al*., 2009). Thus, repeated sprint ability seems to be affected by fatigue. However, Mallo *et al*. (2009) reported the opposite results for referees officiating in high level competitions, noting that these referees performed more high intensity running in the second half during the Confederation Cup and the U17 World Cup. These results suggest that the amount of high intensity running is probably a function of the level of competition, while it also reflects the higher physical fitness levels of the elite referees involved in these competitions. Table 2.5 shows the performance analysis data of football referees retrieved from several studies.

Table 2.5. A summary of the performance analysis data of football referees cited in different studies.

Source	Age (years)	N	Notational method	Total match distance (m)	High speed running (m)	Distance to infringement (m)
D'Ottavio and Castagna (2001) - Elite Italian referees	37 ± 2.1	33	Video analysis	11 469 ± 983	1 546 ± 419	-
Castagna *et al.* (2004)	FIFA referees: 38 ± 3	13	Video analysis	12 956 ± 548	2 378 ± 423	
	Italian referees: 37 ± 3	13		11 218 ± 1 056 ($p < .05$)	1 642 ± 689 ($p < .05$)	-
Weston *et al.* (2005) English Premier league		18	Video analysis	11 617 ± 617	781 ± 208	-
Weston *et al.* (2007) English Premier league	40.1 ± 4.9	19	Computerized video match analysis image recognition system	11 622 ± 739	787 ± 245	14 ± 0.8
Mallo *et al.* (2007)	33.4 ± 3.8	11	Computerized match analysis	11 059 ± 935	1 405 ± 453	First half: 12 ± 5 Second half: 16 ± 7
Mallo *et al.* (2009) FIFA Confederations Cup	39.32 ± 3.43	11	Computerized match analysis	10 218 ± 643	1 920 ± 399	16.3 ± 7.4

m = metres

Heart rate and physical performance

Heart rate is often used as an objective measurement of physiological strain, based on the assumption that there is a linear relationship between heart rate and oxygen uptake (Powers and Howley, 2007; Katch *et al.*, 2011). Subsequently, heart rate is used to estimate energy expenditure and oxygen uptake (Reilly & Gregson, 2006). Heart rate monitors are useful devices that allow the real-time measurement of heart rate and thus the estimation of exercise intensity during training or games.

In a review of the literature, Reilly and Gregson (2006) concluded that most studies agree that the heart rate ranges among referees during a game was 162 to 165 beats per minute (b/min).

Krustrup and Bangsbo (2001) reported mean heart rate measurements of 85 ± 1 % (range 74 – 91 %) of the age predicated maximum heart rate among elite Danish referees (n = 27) during a match. Mallo *et al*. (2009) observed a similar mean heart rate percentage of 86 ± 3 % of the age predicted maximum heart rate among elite FIFA referees in a high level international competition. These results indicated that the match demands required considerable amounts of aerobic energy expenditure with a sizable anaerobic contribution throughout the match. They concluded that the aerobic system was the major source of energy during the match. However, football referees performed high intensity exercise (above 90 % of HR_{max}) for an estimated 28 % of the match, indicating that the anaerobic metabolic system is also stressed. The exercise intensity of the assistant referees during matches has been reported to be lower than that of referees. Krustrup *et al.* (2009) reported a mean heart rate of 124 ± 15 b/min during a match (range: 105 - 157 b/min). Table 2.6 summarizes the heart rates of referees during matches as reported in various studies.

Table 2.6. The mean heart rate data of referees during matches as reported in different studies.

Author	**N**	**Age (years)**	**Heart Rate (b/min)**
Catterall *et al*. (1993) on elite English referees	14		165 ± 8
D'Ottavio and Castagna (2001) on Elite Italian referees	18	37 ± 2.1	163 ± 5
Krustrup and Bangsbo (2001) on Danish elite referees	27	38 (range: 29 - 47)	162 ± 2
Bangsbo *et al.* (2004)		Older referees (n = 15, range 40 to 46 years)	157 ± 3
		Younger referees (n =14, range 29 to 34 years)	167 ± 3
Castagna *et al*. (2005a) on elite Italian referees	8 8	Younger referees: 33 ± 1.8 Older referees: 42 ± 1.2	189 ± 4 176 ± 5
Mallo *et al*. (2009) on FIFA Referees	11	39 ± 3.4	161 ± 9

Despite being a popular measure of exercise intensity, Weston and Castagna (2005) argued that heart rate alone cannot explain the physiological and psychological stress being experienced by referees during matches. Several factors may affect the heart rates of referees during a game. For instance, weather conditions may be conducive to the development of dehydration which will lead to an elevated heart rate. Referees are also exposed to many mental stressors, such as match pressure (from players, coaches and fans), as well as their exposure to performance assessments by match assessors or commissioners during a match. Therefore, match intensity based on heart rate measurements may be overestimated as a result of these factors (Bangsbo *et al*., 2006).

Weston and Castagna (2005) found no correlation between English FA Premier League referees' heart rates and number of high intensity runs ($r = 0.205$, $r = 0.370$, $p > .05$) and there was no correlation between match heart rate and mean distance covered by the referees during the match ($r = 0.370$, $p > .05$). However, they did find a relationship between the number of high intensity runs and distance covered ($r = .540$, $p < .05$). They subsequently recommended that heart rate should be reported together with other physical performance data of the referee to give a realistic estimate of the physical and physiological stress of match refereeing.

Flexibility

The frequent changes in the movement patterns of referees require that they have adequate range of motion in the joints and musculoskeletal system. In their study Bizzini *et al*. (2009a), reported that that hamstring strains (26%) and ankle sprains (26%) were the most frequent types of injuries among the Swiss male referees ($n = 66$). The prevalence of similar injuries was also reported in a study by Gabrilo *et al*. (2013) among Croatian football referees. Bizzini *et al*. (2009a) argued that improvements in the range of motion are important, as it minimizes the risk of injury. According to the American College of Sports Medicine (ACSM, 2012), reduced flexibility in the lower back, posterior thigh region or hamstring muscles is associated with greater risk for chronic lower back pain as a result of poor low back or hamstring muscle flexibility.

The general perception is that improved flexibility minimises the chances of sustaining an injury and chronic conditions like low back pain, however, this view has been questioned. Injuries occur when the muscle is stretched beyond its free range of motion. In a review paper Woods *et al*. (2007) concluded that there were contradicting findings on weather stretching reduced the risk of injury. Pope *et al*. (2000) examined the effect of muscle stretching during warm-up on the risk of exercise-related injury and they found no significant effect of stretching on all injuries ($p = .67$). Furthermore, they found that poor flexibility accounted for 2.5 times the risk of injury, while high flexibility accounted for 8 times the risk of injury when it was compared to average flexibility. Knudson *et al*. (2000) concluded in their paper that only normal levels of flexibility were appropriate to lower the risk of injury. Therefore, flexibility should be optimised for each individual to improve performance and potentially reduce the risk of injury.

Stretching the muscles often is an important activity that helps to maintain or increase flexibility (Harrell 2006; ACSM, 2012) or improve other parameters like power (O'Sullivan *et al*., 2009). If the muscles are not regularly stretched, they become stiff and their range of motion becomes reduced. Trunk and hip flexibility is especially important in reducing the incidence of injury and chronic low back pain and tension (Hopkins & Hoeger, 1992; Minkler & Patterson, 1994). Reduced hamstring flexibility is suggested to be the main cause of hamstring strains (O'Sullivan *et al*., 2009).

Despite the fact that flexibility tests can be a performance related measure it is not included in the FIFA fitness test battery. This is because FIFA fitness tests have largely been based on tests that help predict performance during matches and that depend on normative basis rather than on tests that identify weakness (Mallo *et al*., 2007; Mallo *et al*., 2008). These tests require referees to perform at their maximum effort or level. It is important to assess the flexibility of the referees even though it might not give any performance advantage.

Gleim and McHugh (1997) define flexibility as the ability of a joint to move through its full range of motion. Flexibility can either be static or dynamic. Static flexibility or stretching is described as the range of motion that is controlled and achieved in a slow movement of the joint to in lengthening of the muscle (Woods *et al*., 2007). The purpose of static stretching is associated with the improvement of flexibility (Aguilar *et al.*, 2012) According to Gleim and McHugh (1997) dynamic flexibility is the obtainable range of movement when the joint is moved in a quick motion to its limits. Dynamic flexibility can easily be identified by the stiffness of the muscles or tendons. It is the structure of the joint and elasticity of the muscle and connective tissue (tendons and ligaments) that limits the range of motion. To maintain muscle elasticity regular stretching is required to prevent muscle stiffness (Davis *et al*., 2005).

There are also other factors that limit the range of motion like pain, injury, and the inability to produce enough muscle force, perhaps due to age or illness (Fatouros *et al*., 2002). Physical inactivity can also limit the range of movement in joints due to disuse. An increase in the muscle mass or hypertrophy may also reduce flexibility of a joint (Powers and Howley, 2007). Even though the referees train frequently, are physically fit and are not involved in any physical contact during the match, they are still prone to injuries. Referees are involved in large amounts of sprinting at near maximum to maximum speeds, sudden stops and starts, acceleration, deceleration and change of direction. During these movements, the lower back, hamstrings and calves are constantly in control of the load, rotational movements around the knees and ankle joints. Bizzini *et al*. (2009a; 2009b) reported that hamstring, lower back and calf injuries were common among elite referees and assistant referees.

There are several methods of measuring hamstring and low back flexibility that have been described in the literature. Other methods include utilisation of equipment such as a goniometer and flexometer. These methods have been used to assess the elasticity and plasticity of the skeletal muscles and tendons. The sit and reach test is one test that has been widely used and has appears to be the most popularly used test. However, Hopkins and Hoeger (1992), as well as Lemmink *et al*. (2003) pointed out that there were limitations surrounding the sit and reach test. The limitations are that the test had failed to distinguish between low back flexibility, hamstring length, anthropometric measure of arm length, trunk length and limb length, and calf flexibility and the individual scapular abduction. To counter these limitation of differences in the individual arms and legs limb length and scapular abduction, Hopkins and Hoeger (1992) suggested the modified sit and reach test.

Davis *et al*. (2008) used four different tests to measure hamstring flexibility. They compared results collected from four tests, namely the knee extension angle test, sacral angle test, straight leg raise test and the sit and reach test. Eighty one men and women (mean age 23.6 ± 4.1 years) took part in the study. The results showed poor to fair concurrent validity among the tests and the authors suggested these methods should not be used together to measure hamstring flexibility, because they do not all measure the hamstring flexibility. Minkler and Patterson (1994) used the Leighton flexometer method and the MacRae and Wright method to measure hamstring and lower back flexibility respectively, in order to examine the validity of the modified sit and reach test among 48 male participants (age range: 18 - 35 years). The relationship between these two tests were moderately strong for hamstring flexibility ($r = 0.75$), but poor for lower back flexibility ($r = 0.40$). Collectively the results show moderate validity for the modified sit and reach test to measure hamstring flexibility. Hopkins and Hoeger (1992) contrasted the sit and reach test against the modified sit and reach test for measuring hamstring flexibility among 200 men (age range: 20 - 80 years). They showed that the modified sit and reach was more reliable as it compensated for the arm and leg length differences among participants.

High intensity anaerobic activities

The high intensity activities in football are separated by moderate to low intensity movements that are aerobic in nature. These activities can also be described as active recovery (Bangsbo & Iaia, 2013). Carling *et al.* (2012) reported that high intensity actions during a game were separated by recovery periods lasting 30 to 60 s. Referees constantly have to run at different speeds in an attempt to keep up with play so that they are able to enforce the rules of the game. This ability to sprint and recover sufficiently and quickly to perform the following sprint is called repeated sprint ability (Girard *et al*., 2011). Mohr *et al*. (2005) and Weston and Castagna (2005) consider high intensity running performed by referees as the best indicator of match demands and the development of fatigue, whilst Weston *et al*. (2005) considers the total distance covered by football referees as a poor measure of physical match demands. Therefore, it is of great importance that referees develop the ability to perform high intensity running and repeated activities with short recoveries for the duration of the game.

Krustrup and Bangsbo (2001) reported that referees performed an average of 161 (range 89 to 272) high intensity bouts with a mean duration of 2.3 s (range 1.7 to 3.0 s) during a match, while Krustrup *et al*. (2002) reported that assistant referees on average performed 110 (range 89 to147) high intensity activities with a mean duration of 2.1 s. These high intensity activities usually consist of many short sprints. Girard *et al.* (2011) classified sprints as either intermittent sprints or repeated sprints. The intermittent sprints last up to 10 seconds and have recovery periods between 60 and 100 s that allow an individual to fully recover. On the other hand, repeated sprints last up to 10 s and have brief recovery periods that do not exceed 60 s (Iaia *et al.,* 2009).

Weston *et al.* (2007) observed a relationship between the high intensity running by referees and players during a match ($r = 0.43$, $p < .0001$). These results show that in trying to keep up with the play the referees' match intensity was influenced by the amount of high intensity running by the players. Even though the contribution of high intensity exercises account for a small percentage of the match activities they are critical in reducing the distance to infringements or fouls and in keeping up with play. Therefore, it is critical that referees are physically well prepared so that they can cope with these match demands. High levels of aerobic fitness will ensure that referees stay in close proximity of play and infringements and it will delay the onset of fatigue and its negative effects on decision making capabilities.

Speed

Mackenzie (2014) defined speed as "the quickness of the movement of a limb". Speed can be divided into maximal speed (how fast one can run), optimal speed (controlled speed), acceleration speed (rate of change in speed), reaction time (response time after a stimulus) and speed endurance (the ability to continue running at a constant high intensity pace as fatigue levels increase) (International Association of Athletics Federations manual, 2009). Speed depends largely on the stride length and stride frequency of the individual. Running biomechanics are affected by the individual's height, limb length, muscle fibre type, flexibility, posture and previous or current injuries, to mention a few.

One of the tests that replicate the near maximal high intensity running that is typically observed in team sports and particularly in football is the repeated sprint ability test (RSA) (Oliver *et al*., 2006; Dawson, 2012). The aim of the test is to determine the ability to produce repeated sprint efforts (Dawson, 2012). This test has also been used with football referees and has been found to be a reliable measure of match related fitness (Weston *et al*., 2009). Researchers have recommended different distances and different recovery periods for RSA tests because of the differences in high intensity running match demands that are found in different sports (Spencer *et al*., 2004; Fitzsimons *et al*., 1993). Weston *et al*. (2011a) reported a mean recovery time of 45.1 ± 14.2 s between high speed running activities among elite English referees (n = 59). Watson *et al.* (2009) questioned the 90 s recovery time used in the FIFA 6 x 40 m test, as they argue that it does not equate to the typical exercise to rest ratio in high speed bouts found among football referees during the match. They suggested that the recovery time for the sprint test should be reduced to the 25 s used by Spencer *et al*. (2006) or the 20 s between sprints suggested by Rampinini *et al*. (2007), as these rest periods are closer to the actual match demands.

Mallo *et al*. (2009) reported a mean time of 5.77 ± 0.17 s and a mean fastest time of 5.70 ± 0.17 s among FIFA referees (n = 11) in the 40m RSA test. This study also examined the relationship of the FIFA physical tests and match performance. There was no correlation between the 40 m RSA performance and the distance the referees covered in high speed running during the game (mean 6 x 40 m RSA, r = -0.02, p = .96 and best 6 x 40 m RSA, r = -0.13, p = .74). The conclusion was that this test was a poor predictor of match activities.

Weston *et al*. (2009) recorded a mean time of 5.71 ± 0.19 s (range 5.37 to 5.95 s) and a mean fastest time of 5.59 ± 0.21 s (range of 5.25 to 5.87 s) among elite English referees (n = 17). In an effort to find out if the FIFA tests were measuring the match related physical fitness, they reported that the fastest 40 m RSA time was related to the total distance covered (r = -0.69, p = .002), distance covered in high intensity running (r = -0.76, p < .001) and distance covered sprinting; (r = -0.75, p < .001). From these results, Weston *et al*. (2009) concluded that the fastest 40 m time had sufficient construct validity as a fitness test for referees in football. Even though the 40 m RSA test has been questioned by many it remains part of the FIFA test battery.

Explosive power and muscular strength

In football there are a variety of forceful and explosive movements (Bangsbo *et al*., 2006) which require a degree of muscular strength and power or force. For instance, referees are involved in movements like jumping, sudden turning, changing pace and sprinting during the match. Improved acceleration and speed as a result of increased force in appropriate muscles and muscle groups will improve movement skills such as turning, changing pace during high intensity running and sprinting (Chelly *et al*., 2009). Attaining and developing good levels of muscular strength will allow referees to perform well in activities that require force and power. One important function of muscles is to stabilise and protect the skeletal system. Therefore, good strength levels are also important for injury prevention (Bangsbo *et al*., 2006).

Several test protocols have been used to measure maximal strength. These have included testing of iso-inertial, isokinetic and isometric performances using different types of dynamometers (Abernethy & Wilson, 2000). Although dynamometry provides consistent and accurate assessment on movement it has the limitation that it isolates the assessment of specific muscle groups. This reduces its validity in terms of being a sports-specific test for muscular strength (Svensson & Drust, 2005).

One commonly used iso-inertial strength test is the one-repetition maximum, which is typically used to assess arm or leg strength. It is defined as the maximum load that can be lifted only once. In general leg power is considered important for performance in almost all sport and it is also considered a valuable parameter of functional capacity (the ability to perform activities of daily living) among the general population (Markovic, 2007). The most commonly used test to assess leg power, is the vertical jump (VJ) test. This test can be performed with minimal equipment against a wall with sufficient vertical clearance, or force plates can be used to acquire more precise measurements. The latter have been used to measure jump height in the counter movement, drop and standing jumps with or without weight (Logan *et al*., 2000).

Although the aim of all these tests is to measure leg power or explosive power in a vertical plane, there are differences in the results obtained by the various VJ tests. Ziv and Lidor (2010) reviewed vertical jump performance results in 26 basketball studies. They observed that using different measuring devices and different testing protocols made it difficult to compare the results from various studies. This is considered to be a major limitation in the current literature.

The VJ and sprint test have also been used to determine the relationship between maximal strength and performance (Hoff & Helgerud, 2004). Hoff *et al*. (2002), Storen *et al*. (2008) as well as Helgerud *et al*. (2011) showed that there are more benefits that come with strength and concentric action training programmes than with improvements in leg strength only. Football referees also need good running economy so that they are able to run longer distances during the match using less oxygen while being able to sustain the high intensity levels. Svensson and Drust, 2005 stated that besides the important contribution of strong lower limbs to the performance of athletes, it also contributes to improvements in their standard or level of play.

Castagna *et al*. (2005a) examined the lower limb explosive power performance of 36 elite European male referees, as well as the effect of age on leg power. The referees were divided into three groups; young (aged 31 – 35 years), average (36 – 39 years) and old (40 – 45 years). The older referees scored the lowest VJ results (32.60 ± 3.02 cm), followed by the average aged referees (33.00 ± 2.93 cm) and the younger referees (36.31 ± 3.25 cm). The mean counter movement VJ score for the group was 34 ± 3 cm. There was a significant difference in leg power between older referees and younger referees ($p < .03$) and between younger referees and average aged referees ($p < .03$). Furthermore, Helgerud *et al.* (2011) reported lower explosive power among the referees than for players (57 cm vs. 64 cm).

Castagna *et al*. (2005a) illustrated an inverse relationship between age and leg power, mainly due to the change in muscle fibre type that takes place with ageing, as well as the decrease in cross-sectional area of muscles. Castagna *et al*. (2005a) further states that aging also rapidly declines anaerobic power more than aerobic power. Although referees are not involved in any physical collisions during the match, they should be encouraged to develop their leg strength as much as possible as it would be advantageous to their overall physical fitness.

Agility

The referee and the two assistant referees are faced with frequently having to change activities and direction (from forward sprinting to sideways or backward movements), and need to perform these activities at varied intensities during the match. To keep up with play and be in the best possible position to pick the second last defender for offside decisions, assistant referees need to have the ability to change direction quickly and to stop suddenly when they are required to do so. Assistant referees perform all these activities and movements along the side line while facing the field of play (Krustrup *et al*., 2009). These activities increase the complexity of the referee's task and may affect his/her performance. For the referee to perform these movements, they are required to develop the necessary motor skills. This can only be achieved through effective training. Agility or change of direction ability is, therefore, an important component of the referee's overall fitness profile. Due to the different nature of the assistant referees' movements compared to that of the referee, Krustrup *et al*. (2009) suggested that assistant referees should have specific fitness tests that evaluate their match related activities.

Brown (2003) described agility as the ability to decelerate, accelerate and change direction quickly while maintaining good body control without decreasing speed. Sheppard and Young (2006) defined agility as the ability to rapidly move the whole body with change of speed or direction in response to a stimulus. Both definitions place emphasis on body balance which involves shifting the centre of gravity while in motion. Sheppard and Young (2006) mentioned the importance of responding to a stimulus before performing a movement, which means that agility is a reactive movement skill. For example, the assistant referee will react and follow the second last defender, when the defender sprints backwards when they are under attack. The assistant referee reacts to the vision cues regarding the off-side lines (Castagna *et al*., 2011). Young and Farrow (2013) highlighted in their review that change of direction, perception and decision making are all critical components of agility.

Agility, acceleration and speed or sprinting is often discussed together in the literature. It is important to note that in a sporting context, these three qualities are largely dependent on each other (Bloomfield *et al*., 2007). Speed or sprinting involves running forward at a high velocity, and being a closed skill it is planned or predictable, whereas agility involves quick movements in response to a stimulus (Young *et al*., 2001). Little and Williams (2005) investigated the relationship between speed, acceleration and agility using 106 elite football players. They observed relationships between speed and acceleration ($r = 0.623$, $p < .0005$), acceleration and agility ($r = 0.346$, $p < .0005$) and speed and agility ($r = 0.458$, $p < .0005$). This means that performance in any one of these variables does not predict performance in the other very well. The researchers thus concluded that speed, acceleration and agility were independent qualities.

Agility also depends on the ability to anticipate play, agile footwork, awareness or body control, reaction time, timing and visual processing (Ellis *et al*., 2000). The development of strength plays a role in agility and change of direction activities as body control and footwork is improved as well. If the muscles around the joints are strong, the risk of injury is minimized even though the muscular system is put under stress during agility activities (Bizzini *et al*., 2009b). This iterates the importance of developing the leg strength of referees.

Few studies (Krustrup *et al*., 2002; Castagna *et al*., 2011; 2012) have investigated the importance of agility or change in direction among football referees. There is also no test prescribed by FIFA to evaluate the change of direction ability of assistant referees or referees. In a study to profile elite FIFA assistant referees' match activity, Krustrup *et al*. (2002) recorded 1053 (range 832 - 1459) changes in activities during a match. It was reported that assistant referees change activity every 5s, which consist of an average of more than 110 high intensity running activities, 100 side stepping running and more than 225 change in direction movements during the match.

Krustrup *et al*. (2009) profiled and compared the activities of 14 FIFA referees and 14 FIFA assistant referees. They reported that the assistant referees performed more sideway activities than the referees (160 ± 49 and 5 ± 9, respectively). On the other hand, the referees performed more backwards activities than the assistant referees (86 ± 33 and 7 ± 10, respectively). The number of sprints by the assistant referees and referees during a match was fairly similar (17 ± 5 and 13 ± 4, respectively). Since assistant referees operate along the side-line, they tend to not perform a lot of high speed running (38 ± 10 occasions) and they spend a significant amount of time standing (256 ± 45 occasions). Referees, on the other hand, were involved in more high speed runs (51 ± 19 occasions) and they were standing less (178 ± 37 occasions). The total number of each movement activity for both referees and assistant referees are reported in Table 2.7.

Table 2.7. Match activities of referees (n = 14) and assistant referees (n = 14), adapted from Krustrup *et al*. (2009).

	Standing	High speed running	Sprints	Backward movements	Sideways movements
Referees	178 ± 37	51 ± 19	13 ± 4	86 ± 33	5 ± 9
Assistant referees	256 ± 45	38 ± 10	17 ± 5	7 ± 10	160 ± 49

The results in Table 2.7 show that assistant referees are involved in more sprinting and sideways activities, but in less high intensity running. They often changed direction as illustrated by the large number of standing and sideways activities. This means they are constantly changing direction, and they start and stop several times during the match. It can be concluded that the match activities for referees and assistant referees differ to such an extent that it may necessitate different training methods, i.e. more high intensity training for referees and more lateral running activities for assistant referees. One also has to consider different agility tests for these two groups.

The t-test, 505 agility test, Illinois and other change of direction tests have been used to assess agility and change of direction ability among football players. The aim of these tests is to measure the ability of an athlete to remain in the horizontal plane while performing rapid changes in direction (Sheppard & Young, 2006). For many years, agility or change of direction has been ignored in the FIFA fitness tests and training programmes despite its importance (Castagna *et al*., 2011). In 2008 FIFA introduced physical fitness tests for referees and assistant referees, which aimed to evaluate the repeated sprint ability and intermittent high-intensity endurance of the referees (Weston *et al*., 2009). These tests evaluated and considered only forward running and did not include any component of agility or change of direction (Krustrup *et al*., 2009; Castagna *et al*., 2011). FIFA has also recommended that these tests should be performed on an athletics track (usually tartan tracks) and questions have been raised whether performing the physical test on the tartan athletics track is testing the specific match related demands since football is played on grass turfs (Mallo *et al*., 2009). With the amount of change in direction activities that referees and assistant referees are involved in, it is important that the component of agility or change of direction ability be included in the long term training programme and testing of referees.

Castagna *et al*. (2011) examined the applicability of a new change of direction ability test, called the 10-8-8-10 m test among elite Italian assistant referees (N = 100). There were two groups of referees, namely from Lega Pro (n = 50, age 34 ± 2.0 years, height 177.0 ± 4.9 cm and body mass 75 ± 4.9 kg) and Serie A-B (n = 50, age 37 ± 2.9 years, height 178.0 ± 6.9 cm, body mass 74 ± 6.9 kg). Both groups had six weeks of training for endurance, speed, agility, flexibility and repeated sprint ability. The referees were required to perform three trials with a two minutes passive recovery in between. The best and average times were used for calculations. The results showed that the test did not detect competition level differences between the older and younger referees. Due to the six week training this outcome means that the change of direction ability is a trainable physical ability and that the test can be used to test referees at different levels of competition. Furthermore, the test was perceived as applicable and relevant by assistant referees and that the test contained the specific agility movements that they perform during a match. A score of ≤ 9.67 s was suggested as a good performance score in the change of direction ability test.

Agility is the key to a referees' fitness performance, as a good change of direction ability will enable the referee to keep up with play and be in positions to make the best possible decisions during the match. It is also important that when training for agility, the activities should resemble the actual movements executed during the game as it is a more effective way to meet the neuromuscular demands that are required for a specific performance in the match.

Aerobic capacity

A football game consists of two halves each spanning 45 minutes, separated by a break not exceeding 15 minutes (FIFA, 2013). Despite being an intermittent sport, which includes several bouts of high intensity activities and running, the aerobic system remains the primary source of energy (Bangsbo, 1994; Hoff *et al*., 2002; Stølen *et al*., 2005; Casajus & Castagna, 2007). Castagna *et al.* (2010) pointed out that high aerobic fitness levels contribute to the ability of a player to cover space or long distances and to perform prolonged submaximal activities during a match. The same applies to referees in football, who throughout the match cover long distances on the field in following the play.

Aerobic capacity is typically quantified as the maximum rate of oxygen uptake (VO_{2max}) during exhausting exercise. Individuals with high VO_{2max} values have the ability to sustain activities at submaximal workloads for prolonged periods (Iaia *et al*., 2009). Furthermore, athletes with higher VO_{2max} values recover faster and have larger quantities of stored muscle glycogen. They are also able to use glycogen sparingly during moderate intensity activities, allowing it to be used for higher intensity activities like sprints and allowing the athlete to run further during the game (Wisloff *et al*., 1998).

Krustrup *et al*. (2002) reported a mean VO_{2max} of 45.93 ml·kg·min^{-1} (range 40.9 to 53.6 ml·kg·min^{-1}) among elite Danish assistant referees (n = 12) measured using the incremental treadmill running test. They also found that there was a significant relationship between referees VO_{2max} values and the distance covered during the match ($r = 0.68$, $p < .05$). Furthermore, referees with high VO_{2max} values cover greater distances than referees with lower VO_{2max} values.

Stølen *et al.* (2005) in their review article concluded that, in general, the aerobic fitness levels of referees was not high, probably due to the older age of most referees. Several studies have shown that the aerobic capacity of football referees decreases with ageing (Bangsbo *et al*., 2004; Castagna *et al*., 2004). Caballero *et al*. (2011) reported a mean VO_{2max} of 48.7 ± 4.3 ml/kg/min^{-1} among Spanish referees (26.0 ± 4.9 years). Castagna *et al*. (2005a) reported a higher mean value of 52.10 ml/kg/min^{-1} among younger (33.5 ± 2.5 years) elite Italian referees (n = 8) and a low mean value of 42.50 ± 4.46 ml·kg·min^{-1} among older referees (n = 8) aged 42 ± 1 years.

Several studies have assessed the VO_{2max} levels of football officials using different aerobic capacity tests, such as a cycle or treadmill laboratory test, the Cooper 12 min run test and the multi stage shuttle run or beep test. The problem is that these are not sport specific tests and it lacks relevance to an intermittent sport like soccer (Bangsbo *et al*., 2008). As these tests are continuous in nature it makes it difficult to evaluate the individual's ability to perform repeated intense exercises (Krustrup *et al*., 2002).

Bangsbo (1994) introduced the Yo Yo Intermittent Recovery test (YYIR), which consists of progressively increasing repeated bouts over 40 m, run between markers which are 20 m apart, and with an active recovery of 10 s between bouts. This test assesses an individual's ability to recover from high intensity intermittent exercise and perform repeated intense exercise (Krustrup *et al*., 2003; Iaia *et al*., 2009). The YYIR is a specific test that is used to evaluate physical capacity in intermittent activities like those found in football (Iaia *et al*., 2009). Castagna *et al*. (2005b) showed that the YYIR results did not differ significantly from the 12 min run test ($r = 0.56$, $p < .001$) but they concluded that the YYIR test contained movement patterns that were similar to those observed during the match and that the test managed to discriminate between referees from different levels. Krustrup and Bangsbo (2001) reported a strong relationship between the distance covered during high intensity running in a match and the YYIR ($r = 0.75$, $p < .05$) among 18 elite Danish referees.

Although the aim of the YYIR is not to measure VO_{2max} the latter can be estimated from the results (Krustrup *et al*., 2003; Bangsbo *et al*., 2008; Iaia *et al*., 2009). More importantly, this test can be used to evaluate changes in performance as a result of training (Bangsbo *et al*., 2008). Eighteen referees from Belgium were monitored during a football season and training programmes were prescribed weekly to them (Weston *et al*., 2004). They were tested four times during the entire season using the YYIR Level 1. The FIFA referees improved their performance from 1720 ± 276 m to 2330 ± 268 m, compared with the national elite referees who improved from 1290 ± 407 m to 1985 ± 279 m from the start to the end of the season. A significant change or effect was observed in both groups at the end of the season ($p = .025$). The benefits of the high intensity and intermittent training programme that the referees were exposed to, coupled with their match performance during the season were evaluated using the YYIR test. The fitness levels of FIFA referees have been observed to be higher than lower level referees (Rontoyannis *et al*., 1998). In this study the FIFA referees performed better than the national elite referees although a large improvement was observed among the national elite referees that could be attributed to the high intensity and intermittent training programme to which they were subjected.

Testing and training of football referees

Individual referees should have specific fitness components relative to football refereeing. The physical fitness tests that referees participate in are not only meant to categorise or classify them but they are also meant to detect weaknesses in their performance. When weaknesses have been detected, training programmes can then be prescribed to address it in an effort to improve the referees' performance. Svensson and Drust, 2005 stated that training prescriptions given to athletes should be based on the specific needs of the athlete and their playing position. Similarly, referees will require specific training programmes that are based on their match physical demands to improve performance. Tests should be incorporated in the referees' long term training programmes and can be part of the criterion used for performance prediction, talent selection and identification (Castagna *et al*., 2011).

The role of Executive Cognitive Functioning in refereeing performance

High levels of physical fitness and a good knowledge of the rules of the game are not enough for a referee to successfully officiate a game. Da Silva and Fernandez (2003) noted that a great deal of time and resources has been spent on improving the physical fitness levels and the perceptual-cognitive skills of referees to meet the match demands. Refereeing requires effortful cognitive processes that are controlled, conscious and intentional as they interpret and apply the laws of the game (Chodzko-Zajko *et al*., 1994). According to Helsen and Bultynck (2004) the quality of the refereeing decisions during a game is the most important aspect of officiating matches.

The decisions made by referees are influenced by internal factors (e.g., fatigue, dehydration and anxiety), external factors (e.g., players, coaches and spectators), different tasks (including ball location or player position) and the contexts in which certain events occur (either during or outside playing time) (Helsen & Bultynck, 2004; Johnson, 2006). Referees also have to be well positioned; close to the action and at an angle that gives them a clear view of the play (Mascrarenhas *et al*., 2002; Weston *et al*., 2012). During the game, referees are sometimes put under additional pressure by the fact that there is an assessor evaluating their performance (FIFA, 2010).

Helsen and Bultyack (2004) observed that elite referees made an average of 137 (range 104-162) observable decisions per match, with an average of three to four decisions per minute. These decisions tend to be made spontaneously, dynamically, under highly pressurised settings and may have a great influence on the outcome of a match (Johnson 2006; Karademir 2012). Helsen *et al*. (2007) showed that refereeing is cognitively demanding. Optimal executive functioning is, therefore, essential for referees to effectively officiate matches (Chang and Etnier, 2009).

Executive Cognitive Functioning

Cognition is the processing of information by the central nervous system and involves perception, memory, vigilance, speed or reaction time, attention, problem solving etc. (Tomporowski, 2003; Chodzko-Zajko *et al*., 2009; Alves *et al*., 2012). Executive functioning refers to the control of complex thoughts and the regulation of behaviour (Spirduso *et al*., 2008). It entails a higher level of the cognitive process that is responsible for organising and ordering behaviour, including logic and reasoning, abstract thinking, problem solving, planning and execution.

On the most anterior part of the frontal lobes is the prefrontal cortex that is responsible for executive control, decision making, attention switching, planning, goal setting, emotion, working memory, conflict monitoring etc. (Dempster 1992; Goldberg & Bougakov, 2007). High levels of executive cognitive function (ECF) are required to select task relevant information and to eliminate less important information during an activity. ECF also aids in connecting past experiences with the current situation.

ECF is vital in activating the working memory, and to enable an individual to focus on a task and to switch between tasks. A person is able to organise present information, select and execute the correct action, control or inhibit interferences and remain focused on the task at hand (Verhaeghen & Cerella, 2002). This working memory could include both short term and long term memory. Therefore, optimal ECF is needed by referees to enable them to make decisions amidst a variety of physically demanding conditions and external interferences. This would also allow referees to use past learned experiences to make fair and balanced decisions during the game.

Factors affecting decision making in refereeing

In an effort to help referees learn from past experiences, as well as to improve decision making ability during games, FIFA has introduced digital video training material for referees (Helsen & Bultynck, 2004; MacMahon *et al*., 2007; Catteeuw *et al*., 2009). These video training programmes have become a useful tool in standardising the decisions and judgements made by referees in different match situations (Catteeuw *et al*., 2009). However, multiple factors affect ECF during exercise (Ando *et al*., 2011), which are not necessarily addressed by these video training programmes. Referees have to develop the ability to ignore irrelevant data or information as well as other disturbances that may affect their judgement, whilst focusing on the play and applying a good sense of judgement (Rontoyannis *et al*., 1998).

Referees are required to pay full attention to each and every game situation and to make quick, but accurate decisions (Helsen *et al*., 2007). They have to shift their attention from broad to narrow (and vice versa) depending on the dynamics of the game and to avoid or minimise the effect of any negative internal or external factors (Weinberg & Gould, 2011; Weston *et al*., 2012). An inability to control their attention and to remain focused on the task at hand may also induce stress and mental fatigue (Warm *et al*., 2008; Moore *et al*., 2012). The success of a referee relies on their ability to make the correct decisions under pressure, which depends on their ECF.

It is important for referees to concentrate on relevant visual and audio stimuli from the environment for them to make correct decisions. Some of the stimuli are unimportant and may in fact be distracting to the referee. This ability to effectively inhibit or suppress irrelevant stimuli is sometimes lost due to aging (Dempster, 1992). Starting from roughly the age of 30 years, there is a gradual decrease in the density of the neural tissue in the frontal lobes, which contributes to the reduction in ECF (Dempster, 1992; Fotenos *et al*., 2005; Antunes *et al*., 2006). Such age related declines may include, among other effects; slower reaction times, slower speed of information processing, reduced memory retrieval and decrements in visual-spatial problem solving ability (Emery *et al*., 1995). A decline in ECF experienced by ageing referees may negatively affect their performance and decision making abilities despite their years of experience.

Referees' poor physical fitness may contribute their poor decision making. The referee may fail to keep up with play, due to the fast pace of the game. On the other hand the assistant referees may fail to position well for off-side decisions due to lack of fitness (Krustrup *et al*., 2009). Lack of physical fitness may also affect the referees cognitive functioning and ability to make correct decisions (Reilly & Gregson, 2006).

Tests of ECF

Several tests have been developed to measure different cognitive functioning domains including attention, vigilance, working memory, interference control, planning, visual motor functioning, spatial problem solving, psychomotor functioning, speed of processing, visual learning and memory, as well as verbal learning and memory (Dempster, 1992; Chodzko-Zajko *et al*., 1994). In a number of these tests reaction time and response accuracy are used as the measure of performance. Some of the most commonly used tests to measure different components of executive cognitive functioning are the Tower of London test, Flanker test, Stroop test, Wisconsin card sorting test, Vigilance test, Stop signal task and Letter memory task. Table 2.8 provides an overview of different ECF tests that have been commonly used to measure various cognitive functions within the context of physical activity.

Table 2.8. An overview of studies that have used various executive cognitive tests.

Test used	**Cognitive functions**	**Topic of the study**	**Source**
Eriksen flanker test	Information processing and Interference inhibition	Effects of cerebral oxygenation on cognitive function during exercise.	Ando *et al*. (2011).
		Effects of acute moderate intensity exercise on ECF.	Soga *et al*. (2015).
Tower of London test	Planning and Problem solving	Effects of acute moderate aerobic exercise on planning and problem solving among college students.	Chang *et al*. (2011).
Stroop task	Selective attention, Inhibition and Interference	Effects of an acute bout of resistance exercises on cognitive performance in middle aged adults.	Chang and Etnier (2009).
		Areas of the lateral prefrontal cortex that experience activation level changes due to Stroop interference during acute moderate exercise.	Yanagisawa *et al*. (2010).
		Effects of aerobic and strength exercises on ECF in middle aged adults.	Alves *et al*. (2012).
		The dose response relation between exercise duration and cognitive function.	Chang *et al*. (2014).
Trail making test	Inhibition, Executive processing, Concentration and Cognitive flexibility	Effects of an acute bout of resistance exercise on cognitive performance in middle aged adults.	Chang and Etnier (2009).
		Compared the effects of aerobic and strength exercises on ECF in middle aged adults.	Alves *et al*. (2012).
Wisconsin card sorting test	Interference inhibition	Specific frontal lobe lesions that demonstrate performance deficits during interference tasks.	Dempster (1992).
		Shifting, information updating and inhibition among college students.	Miyake *et al*. (2000).

Miyake *et al*. (2000) emphasised three common executive functioning tasks; monitoring and updating of working memory, attention and inhibition. Attention is one of the fundamental executive cognitive functions (Lansbergen *et al*., 2007) and has manifested in individuals as divided, sustained or selective attention (Salo *et al*., 2001). In recent years, researchers have used the Stroop Colour-Word test to demonstrate interference in attention (or conflict resolution) and to measure the speed of information processing (i.e., reaction time) as well as the selective attention capacity of participants (MaCleod, 1991; Liu-Ambrose *et al*., 2010).

MacKinnon *et al*. (1985) described the Stroop effect or interference effect as the difficulty or amount of time taken by a participant to remove relevant information from incongruent information during a task. Response time tends to be slower when the colour and words are incongruent or different. The Stroop effect can also be expressed in the form of proponent response or facilitation, where one mental process reinforces the performance of another mental process (Lansbergen *et al*., 2007). The physical demands placed on referees, various distractors they are exposed to during the game and the subsequent onset of fatigue may cause referees to loose attention and make incorrect decisions (Krustrup & Bangsbo, 2001).

MacKinnon *et al*. (1985) studied the effects of effort on Stroop task interference. The participants included 64 male and female students that were divided into an experimental and control group. The experimental group performed the Stroop task as a competition with a high incentive at the end of the test and the control group performed the task in a non-competition setting. They used the pre and post test results to measure if there were any differences or improvements. They found that participants in the high incentive group managed to significantly reduce Stroop interference ($p < .05$). Furthermore, they found that the participants in the high incentive group exerted greater effort on the task at hand than the control group ($p < .001$) and in doing so were more able to inhibit the distractors. The participants in the control group were able to restrict their attention to fulfilling the required instructions and colour cues, but took longer to complete the task.

The effect of exercise on ECF

Several studies have shown that exercise improves ECF and these improvements are due to physiological and cognitive mechanisms. As noted before, referees are involved in recurrent activities at various intensity levels during a match which usually lasts in excess of 90 minutes. Referees have to perform these functions in very demanding physical, psychological and environmental conditions (Da Silva & Fernandez 2003; Helsen & Bultynck, 2004; Reilly

& Gregson 2006; Weston *et al*., 2012). They require high fitness levels, as a lack of fitness could affect their decision making ability due to poor positioning and failing to keep up with play (Helsen *et al*., 2007). In this regard, Kruger *et al*. (2012) identified concerns about physical fitness as the dominant stressor experienced by South African football referees.

Fitness levels, or in particular a lack of fitness also affects refereeing performance as unfit referees would also start to fatigue earlier in a match. Fatigue increases human error and leads to reduced physical and mental performance (Moore *et al*. (2012). Edwards (1983) defined fatigue as “the inability of the total organism to maintain a predetermined exercise intensity” (p. 3). Weinberg and Gould (2011) stated that “fatigue reduces the amount of processing resources available to the athlete (referee) to meet the demands of the situation” (p. 376). This implies that fatigue contributes to poor decision making due to a decrease in the information processing resources as a result of changes in a host of physiological factors, for example the intramuscular changes, energy depletion, potassium imbalance, lactic acid and hydrogen ion accumulation (Reilly, 1997). Two types of fatigue can be distinguished; peripheral fatigue and central nervous system fatigue (Davis & Bailey, 1997; Meeusen & Roeland, 2010). Peripheral fatigue refers to dysfunctional muscle contraction during exercise, whilst central nervous system fatigue entails fatigue of motor drives that are related to the central nervous system circuits connected to the brain and involved in ECF (Moore *et al*., 2012). Central nervous system fatigue has been attributed to changes in brain neurotransmission, a possible inhibition of brain oxidoreductive processes and to hormonal changes in the circulation due to exercise (Meeusen & Roeland, 2010).

Referees have been shown to experience fatigue or reduced performance for a period of five minutes after the most intense five minutes of high intensity running during each half of the match (Mallo *et al*., 2009). This finding shows that performance is reduced after a period of high intensity exercise, during which referees try to exert less effort on other activities in order to save their energy for the remainder of the match (Weston *et al*., 2012). Referees cannot be substituted (unless they get injured) and have to follow the play during the entire game, implying that they have little time to recover (Stølen *et al*., 2005).

Audiffren (2009) classified physical exercise according to the energy pathway (aerobic or anaerobic), mode of exercise progress (constant or incremental load), intensity and duration. These factors may have positive or negative influences or effects on ECF. Researchers have explored how these factors independently and collectively affect ECF. Tomporowski (2003) concluded that moderate aerobic exercises of up to 60 minutes had a positive effect on information processing, but that activities which went beyond 60 minutes may likely have a negative effect on cognitive function. In a review, Lambourne *et al*. (2010) found conflicting results about the effect of exercise on cognitive functioning. They concluded that cognitive function may be enhanced or impaired depending on the type and duration of exercise performed.

Over the last few years, researchers have provided evidence that acute aerobic and low moderate intensity exercises that lasts approximately 30 minutes leads to improved ECF, while high intensity exercise has a negative effect on ECF (Audiffren, 2009; Yanagisawa *et al*., 2010; Chang *et al*., 2011; Alves *et al*., 2012). Audiffren (2009) attributed the positive effects of moderate duration aerobic exercise on ECF to the fact that the participants performed the exercise in a steady state and that there was limited central and peripheral fatigue. Nanda *et al*. (2013) examined the acute effects of 30 minutes of moderate intensity (60 - 70% of VO_{2max}) aerobic exercise on ECF among 10 male participants. Memory, reasoning, concentration and planning were tested both before and after exercise. The results showed a significant improvement in memory using the paired associates test ($p = .01$), reasoning using the odd one test ($p = .003$), concentration and planning using the spatial slider test ($p = .043$) as well as a decrease in the total time taken to complete the tests (pre: 23.5 ± 2.55 s, post: 21.2 ± 1.48 s, $p = .03$) following the exercise protocol. This study demonstrated the benefits of moderate intensity aerobic exercise on cognitive functioning.

Chang *et al*. (2014) examined the dose-response relationship between exercise and cognitive function among 26 men with a mean age of 20.77 ± 0.91 years. Three exercise protocols were performed in random order by the participants; exercise that lasted 10 minutes, 20 minutes and 45 minutes at 65 % heart rate reserve (resting heart rate + 70 % difference between age predicted HR_{max} and resting HR). The 65 % heart rate reserve was considered to be of moderate intensity. Heart rate was recorded at rest and during the exercise to monitor the intensity of exercise. The Stroop task was administered after every exercise bout. Results showed that moderate intensity exercise that lasted 20 minutes was significantly more effective in facilitating improvement in terms of the time taken to complete the Stoop task compared to the 10 minutes and 45 minutes exercise bouts ($p = .02$). The response time was lower and a higher score was obtained for accuracy which indicates better performance.

Audiffren (2009) reported an inverted–U shaped relationship between arousal levels and cognitive functioning during exercise; this is linked to the increase in exercise that facilitates improvement in cognitive function. Cerebral oxygenation has been shown to affect cognitive function during exercise (Ando *et al*., 2011). Cassilhas *et al*. (2007), as well as Rattray and Smee (2012) concluded that cognitive function improved during exercise ranging between 60 and 80 % of $VO2_{max}$ as a result of peak oxygenation experienced in the frontal lobe. Cassilhas *et al*. (2007) argued that improved blood flow as a result of exercise to the brain and central nervous system facilitated the movement of oxygen and other nutrients needed. However, Ando *et al*. (2011) found that cerebral oxygenation during exercise at the same intensity level was no different to that at rest and that the improvement in cognitive function was independent of cerebral oxygenation.

Other factors that promote cognitive functioning

Apart from participating in regular exercise, there are many other factors that can promote cognitive functioning or decision making, either in the short term or long term, as well as for match-related requirements and daily life. Bostron and Sandberg (2009) suggested that education and training were important factors that could improve concentration, memory and critical thinking necessary for cognitive functioning. Education and training would allow referees to be better equipped on the knowledge of the laws of the game of football and practical application thereof during matches. Visual and tracking skills are also critical for match officials for making quick, accurate and good decisions under different match conditions (Pietraszewskia *et al*., 2013). Vigilance and visual training is, therefore, necessary and can be improved over time through practise and training under supervised conditions. Catteeuw *et al*. (2010) attempted to create video training materials of match situations to help referees improve on their decision making so as to reduce errors during the match. Pinilla (2008) also showed that when a proper diet and exercise are combined, they can affect mitochondrial energy production, which in turn is vital for sustaining neuronal excitability, as well as synaptic and cognitive function.

Factors such as dehydration and hyperthermia could also contribute to the development of fatigue and a decline in cognitive function when athletes exercise in the heat or unfavourable weather conditions (Mohr *et al*., 2005). Referees often officiate in environments where they suffer moderate dehydration (Da Silva & Fernandez, 2003). During prolonged and strenuous physical activities, body temperature may rise due to high ambient temperatures and high humidity, further restricting body heat loss and resulting in reductions in performance (Maughan & Shirreffs, 2010). Davis and Bailey (1997) stated that performing continuous physical activity leads to a reduction in energy reserves and may lead to dehydration which will affect mental performance if a person does not drink enough fluids. The decline in the cognitive or mental performance also has a negative impact on decision making. It has been reported that a loss of total body water at a level of 2 % body mass has negative effects on cognitive functioning (Sharma *et al*., 1986; Lieberman, 2007).

Da Silva and Fernandez, 2003 studied body water and body mass changes as a result of officiating matches among 12 Brazilian referees. The matches took place at an average temperature of 20˚C. The participants emptied their bladders before the match and their body mass were measured. Their water intake and urinary volume during half time were used to calculate total body water loss. After the match the referees' body mass was measured again. It was found that the referees lost 2.05 ± 0.18 % of total body water and 1.55 ± 0.12 % in body mass. The assistant referees lost 1.05 ± 0.25 % of total body water and 0.63 ± 0.17 % of body mass. Despite the moderate temperature the referees lost a significant amount of total body water during the match. Maintaining an appropriate level of hydration during exercise is, therefore, important as it Morh *et al*. (2010) showed that it prevents a decrease in cognitive functioning.

Summary

This overview of the available literature has discussed body composition, physical fitness and ECF as critical elements that contribute to successful refereeing performance. There are knowledge gaps with regard to these topics among football referees in Africa and in particular Zimbabwean football referees. Further research into these key elements will enable those working with referees to develop and implement better training programmes to assist referees in reaching adequate performance levels. Such findings will also help to establish baseline data that can be used in the identification, selection and career development of referees in Zimbabwe. The next chapter will outline the procedures used in the current study on elite male Zimbabwean referees to gather their body composition, physical fitness and cognitive functioning data.

Chapter 3
Research Methodology

Study design

This study employed a non-probability sampling technique with participants being conveniently selected. The study collected quantitative data and was descriptive in design. The participants were sampled purposefully and due to the descriptive nature of the study there was no control group. A one-group pretest-posttest design was used to determine the effect of a fatigue-inducing protocol on executive cognitive functioning.

Participants

The participants were 41 male Zimbabwean FIFA (licensed) international referees and Zimbabwe Football Association (ZIFA) Premier League referees (See Table 3.1).

Table 3.1. Study participants and group breakdown.

	Group	ZIFA	FIFA	Referees	Assistant Referees
Number	41	33	8	21	20

To participate in the study referees had to be registered as 2013 FIFA and/or ZIFA Premier League referees. All of the referees passed the category one referee or assistant referee FIFA physical fitness test in May 2013. Participants were excluded from the study if they were older than 45 years of age and had any medical condition or illness at the time of the study which may have inhibited their performance during testing. Referees were also excluded if they sustained an injury within the last three months before the start of the study.

Research assistants

Five research assistants from the Department of Sports Science and Coaching (National University of Science and Technology (NUST), Bulawayo, Zimbabwe) and one research assistant from the Department of Sport Science (Stellenbosch University) assisted with data collection. The five research assistants from NUST were all accredited level two International Society for the Advancement of Kinanthropometry (ISAK) anthropometrists. The research assistants were trained during a pilot study that was held on 10 August 2013 at the National University of Science and Technology in Bulawayo.

Pilot study

As recommended by Norton and Olds (1996), a pilot study was conducted to help the researcher and research assistants to become familiar with the data collection tools, procedures, to standardise the measurement techniques and to improve the efficiency of taking measurement before undertaking the main study. The pilot study focused on the anthropometric procedures, minimising errors and to improve on time management during the main study. Six class one referees participated in the pilot study.

Ethical issues

The study protocol was approved by the Research Ethics Committee: Human Research (Humanities) of Stellenbosch University (DESC_Banda2013, Appendix One). Permission to carry out the study was granted by the Zimbabwe Football Association Referees Committee (Appendix Two). The procedures did not include any invasive procedures and the participation was voluntarily. The participants were informed that they could withdraw from the study at any time. Participants who decided to take part in the study were asked to complete an informed consent form that was explained in full and participants were allowed to ask questions.

Procedure

The participants were informed of the study by the Secretary General of the Zimbabwe Referees Committee (via email and a short text message). On arrival at the test venue, a meeting was held with the participants in the presence of the Zimbabwe Referees Committee executive members, where they were informed about the aims of the study and the procedures. A similar meeting was held in Bulawayo before the second round of testing.

The first phase of data collection was held during the FIFA Member Association Elite referees workshop (18 and 19 August 2013), at Prince Edward High School in Harare, Zimbabwe. There were 31 referees who attended the course from the total number of 41 referees on the ZIFA panel. The remaining 10 referees were tested on 30 August 2013 at the Elangeni Training Centre in Bulawayo during the national referee's refresher course.

Table 3.2 show the testing schedule for day one and two. The first phase comprised of two testing days. On day one the following data and measurements were collected: anthropometric measures and body composition, flexibility (modified sit and reach test), leg power (vertical jump), strength and muscle endurance (one minute sit up and one minute push up). Not all of the tests that were conducted on day one were included in the tests prescribed by FIFA. The anthropometric measurements, modified sit and reach, vertical jump, 1 minute push up and 1 minute sit up tests were added due to its importance and frequent use in the available literature. On the second day of phase one the referees performed the 6 x 40 meters repeated sprint ability test, using the FIFA fitness test protocol (FIFA, 2010). The second phase began two weeks after the first testing dates and took a month. During the second phase of testing, the referees performed the modified Stroop task before and after completing the Change of direction ability (CODA) test and the Yo Yo intermittent recovery (YYIR) level one test. The research team visited the referees in their home towns around the country to collect data after failing to regroup the referees as planned, due to their work and match assignments.

Testing

The study consisted of two phases (see Table 3.2). The first phase formed part of the annual FIFA Member Association course which started on 18 August 2013. The second phase of the study started on 8 September and was completed by 15 November 2013.

Table 3.2. Phase 1 and 2 testing schedule.

	Phase 1 Test schedule:
	Day 1:
1	Anthropometric measurements
2	10 minutes Warm up with Dynamic Stretching Exercises
3	Modified Sit and Reach (Flexibility)
4	Vertical Jump (Leg power)
5	1 min Push up (Strength and muscular endurance)
6	1 min Sit up (Strength and muscular endurance)
7	10 minutes Cool Down with Static Stretching Exercises
	Day 2:
1	10 Minutes Warm up with Dynamic Stretching Exercises
2	6 x 40m Repeated Sprint Ability (Speed)
3	10 minutes Cool Down with Static Stretching Exercises
	Phase 2 Test schedule:
1	Stroop task (Pre-test)
2	10 minutes warm up with Dynamic Stretching Exercises

3	Change of Direction Ability (CODA) test
4	Yo Yo Intermittent Recovery Level 1 test (with heart rate recorded)
5	Stroop task (Post-test)
6	10 minutes Cool Down with Static Stretching Exercises

A medical doctor linked to the Zimbabwe Referees Committee assisted with the pre-test medical check-up of the participants during the annual FIFA Member Association course. It is a FIFA requirement that where physical fitness tests are to be held, a medical doctor should carry out a pre-fitness test medical check to ascertain if the referees are fit to undertake the test. All of the participants were cleared to be tested.

Anthropometric measurements

The measurements of stature, body mass, six skinfolds, five girths and two bone breadths were collected according to the standard procedures described by ISAK (Marfell-Jones *et al*., 2006).

Stature (stretched height)

The stature was measured using a Seca Stadiometer model 213 1721009 (Hamburg, Germany) which measures the height between the vertex and the inferior aspects of the feet. The procedure followed the one described by Marfell-Jones *et al*. (2006). The participant stood on the base of the stadiometer in a perpendicular position, heels, buttocks and back of the head slightly in contact with the upright ruler or scale of the stadiometer. The head of the participant was positioned and held using the tips of the thumbs on each orbital to achieve the Frankfort plane. The participant was requested to take and hold a deep breath at which time the kinathropometrist slightly and gently lifted the participant's head upward whilst keeping the head in a Frankfort position. An assistant placed the head board on the vertex of the participant's head and the height was recorded to the nearest 0.1 cm.

Body mass

Body mass was assessed using a Seca Clara 803 digital scale (Hamburg, Germany). Participants were asked to remove their shoes and any excess items or clothes, stand upright on the scale, with hands placed on the side of the body and facing forward. The body mass was recorded to the nearest 0.1 kg.

Skinfolds

The following skinfolds were taken on the right-hand side of the body using the skinfold calliper (Slimguide model): triceps, subscapular, supraspinale, abdominal, front thigh, and medial calf. The landmarks were measured and indicated on their respective sites before taking all skinfold measurements as explained by Marfell-Jones *et al*. (2006). In all cases measurements were taken twice and the average of these measurements was used. In cases where the first two measurements differed by more than 5% a third measurement was taken and the median value was used for further analysis, as recommended by Eston *et al*. (1996).

Girths

The following girth measurements were taken using an anthropometric tape: arm (relaxed), arm (flexed and tensed), waist, gluteal and calf. Where applicable, these measures were taken on the right-hand side of the body.

Bone breadths

The distance between the medial and lateral epicondyles of the humerus and femur was measured using the small sliding callipers for bone breadths according to the methods described by Norton and Olds (1996). These measures were taken on the right-hand side of the body.

Anthropometric calculations

The measures were used to calculate the sum of six skinfolds, estimated percentage body fat, body mass index and somatotype using the following formulas:.

Sum of six skinfolds (mm) (Casajus & Castagna 2007).

= triceps + subscapular + supraspinal + abdominal + front thigh + medial calf.

Percentage body fat (%) (Reilly *et al*., 2009).

= 5.174 + (0.124 x triceps) + (0.147 x abdominal) + (0.196 x front thigh) + (0.13 x medial calf).

Body mass index (kg/m^2) (WHO, 1995).

= body mass/height^2

Somatotype (Norton & Olds, 1996)

Endomorphy

$= -0.7182 + 0.1451Y - 0.00068Y^2 + 0.0000014Y^3$

Mesomorphy

= 0.858 × humerus breadth + 0.188 × corrected arm girth + 0.161 × corrected calf girth – height × 0.131 + 4.5.

Ectomorphy

The ectomorphy component was calculated using the height – weight ratio (HWR) according to the stated conditions:

1. If HWR is greater than or equal to 40.75,
   then: Ectomorphy = 0.732 × HWR – 28.58
2. If HWR is less than 40.75 but greater than 38.25,
   then: Ectomorphy = 0.463 × HWR – 17.63
3. If HWR is equal to or less than 38.25,
   then: then: Ectomorphy = 0.1.

Where: Y = Σ3SKF (triceps, subscapula, and supra-spinale skinfolds).

Corrected for height by multiplying Σ3SKF by 170.18 ÷ height (in cm).

HWR = height over cube root of mass.

Physical fitness assessments

All participants were required to warm up for 10 minutes before the tests. A demonstration with instructions was given for all the activities. Participants were allowed up to three practise trials for each activity after the demonstration.

Flexibility

Modified sit and reach test

Purpose: The test measures flexibility of the hamstring muscles and lower back (Hopkins & Hoeger (1992); Mayorga-Vega *et al*., 2014). Lack of flexibility in the lower back and hamstring muscles is associated with muscular pain in the lower back, gait limitations and increased chances of falling (ACSM, 2012; Mayorga-Vega *et al*., 2014). The modified sit and reach test has been used and validated by Minkler and Patterson 1994 and Lemmink *et al*. (2003).

Procedure: The test followed the one described by Hopkins and Hoeger (1992). The participants were asked to remove their shoes and to sit on the floor with their back against the wall and their legs stretched and flat on the ground. The sit and reach box was then placed against their feet. The participants were asked to stretch their arms out without moving their back from the wall. Their hands were place one on top of the other and with the middle fingers level and then placed above the sit and reach box ruler. The first reading was taken at the fingertips of the stretched arms to mark zero. The participants were asked to reach or lean forward slowly as far as they could without flexing knees. During the test, the participants were not allowed to jerk or bounce as they reached or leaned forward. The distance reached from the zero mark was recorded. Three trials were allowed for each participant and the best distance was used for further analysis.

Strength, power and muscular endurance tests

The participants performed three tests for strength and muscular endurance; the vertical jump, one minute sit up and one minute push up test. A 10 minute warm up using static and dynamic stretches was allowed for participants before the tests to minimise the risk of injuries.

Vertical Jump test

Purpose: This test assesses the explosive power of the legs. Reilly *et al.* (2000) pointed out that actions like jumping, kicking, tackling and changing pace are explosive and forceful. These activities require power output related to leg muscle strength. There are many vision of vertical jumps that use different jumping techniques (squat jump, countermovement jump and drop jump), apparatus and machines (force plat forms, contact mats or high speed video analysis, and field tests) (Logan *et al*., 2000; Menzel *et al*., 2010). The vertical jump test used in this study follows the countermovement jump field test described by Logan *et al*. (2000) and Markovic and Jaric (2007).

Procedure: The test was carried out on a plastered wall with a concrete floor inside the testing venue. The wall had a good vertical clearance. Each participant put chalk dust on their middle finger and stood with their side facing the wall and their arms stretched out. Without lifting their heels, the participant marked on the wall with the middle finger the highest point they could reach (standing reach). This mark was recorded. The participant took a step away from the wall, opened their feet shoulder width apart and jumped off the ground with both feet together. The participant attempted to touch the highest possible point on the wall. The participants were allowed to swing their arms and flex their knees so as to gain maximal vertical velocity. The participants were not allowed to make any counter movements before the jump. The distance between the standing height and the jumped height was measured and recorded as the test results. The participants were allowed three trials. The final score was the best distance jumped from the three attempts by subtracting the referee's standing reach height from the highest height jumped.

One minute sit up test

Purpose: The test measured the muscular endurance of the abdominal muscles. The test has been used elsewhere by Esco *et al*. (2010).

Procedure: The test follows the one that was described by Esco *et al*. (2010). The participants were asked to lie on the floor with their knees bent at a 90º angle and to place both hands on the opposite shoulders across the body. A partner held down their ankles. A time keeper with a stopwatch commanded "go" to start the test and the participant raised their upper bodies forward until their elbows touched their thighs. The participants attempted to perform as many sit ups as possible in one minute without losing the described form. They were allowed to pause or rest during the minute. The maximum number of sit ups performed in the correct form was recorded as their final score.

One minute push up test

Purpose: The test measures the strength and endurance of the arm and shoulder-girdle strength (upper body muscles) (Baumgartner *et al*., 2002; Esco *et al*., 2010). The test has shown to be a valid and reliable test to measure the upper body muscle strength and endurance as reported by Romain and Mahar (2001) and Baumgartner *et al*. (2002).

Procedure: The testing procedure followed that outlined by Baumgartner *et al*. (2002). The participants were asked to lie on the ground (assume the prone position) and to place their hands next to their shoulders. The participants assumed the starting position by extending their arms into a straight position. The participants faced forward and kept their body straight at all times. When performing the push up the participants lowered their bodies until their elbows are bent to 90° with the upper arm parallel to the floor as described in FITNESSGRAM (1999). Participants had to touch a clenched fist placed underneath their chest by the co-examiner so as to make sure that their body is lowered and an angle of 90° is achieved at the elbows then they push up to return to the starting position. A time keeper gave the command "go" to start the one minute and "stop" to end one minute. The maximum number of correctly completed push ups in one minute was recorded as the score.

Speed test

40 meter Repeated Sprint Ability (RSA) test

Purpose: The 40 m RSA test was used to measure the anaerobic performances of the referees (Fitzsimons *et al*., 1993) and their ability to recover after short periods of rest. This test has shown to be relevant to referees as a measure of match related fitness (Weston *et al*., 2009).

Procedure: The procedure of the test followed the protocol established by FIFA (FIFA, 2010). The referees ran six 40 m sprints with 90 seconds recovery or rest intervals between each bout (Caballero *et al*., 2011). The 40 m fast run or sprint was performed on the tartan athletics track and athletes performed the test with sports shoes. The use of athletics spike shoes was not allowed. The referees attempted to complete each sprint in less than 6.2 s, whereas the assistant referees attempted to complete each sprint in less than 6.0 s. Referees that failed to complete the run in the given times were allowed one extra sprint at the end. A second run outside the required times warranted failure of the test. The referees used the standing start position 1.5 m behind the zero meter line. There were two photoelectric beams (Microgates, Racetime2 kit light radio model, Italy) to record the time. One of the photoelectric beams was placed at the zero mark and the other at the 40 m mark. The referees' fastest and average times in 6 x 40 m sprints were used for analysis.

Agility

Change of Direction Ability (CODA) test

Purpose: The 10-8-8-10 m test is an agility test designed specifically to assess the quickness of movement in the change of direction ability of football assistant referees.

Procedure: The test followed the procedure developed and proposed by Castagna *et al*. (2011). The test was performed on the grassed football pitch, with cones place along the side line. The referees were allowed only to use sports shoes. The referees would start the test 1.5 m from the starting line where a set of speed lights (Microgates Racetime2 kit light radio model (Italy)) were placed. The participants sprinted 10 m forward from the starting line, turned back, side shuffled for 8 m, turned, side shuffled 8m, turned and sprinted forward 10 m back to the starting line to finish the test (see Figure 3.1). Each participant performed three trials separated by a passive recovery (walking around or standing) of two minutes in between. The fastest and mean times were used for further analysis.

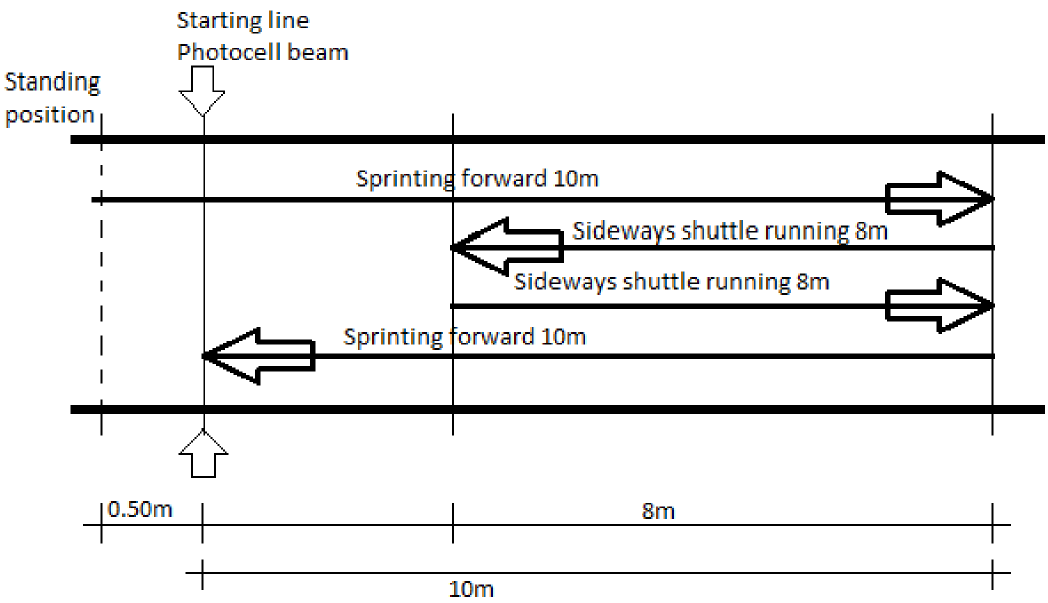


Fig. 3.1. Illustration of the Change of Direction Ability test as described by Castagna *et al.* (2011)

Aerobic endurance

Yo Yo Intermittent Recovery (YYIR) Level One test

Purpose: The test focuses on the capacity to carry out intermittent exercise leading to a maximal utilisation of the aerobic system. The test also determines the ability of athletes to recover from intense exercise (Iaia *et al.*, 2009).

Procedure: The YYIR level one was carried out on a standard football playing field with a grass surface. Referees performed the YYIR level one test wearing sports shoes. The YYIR level one test consisted of two 20 m shuttle runs performed at increasing velocities, with 10 s of active recovery (walking around a cone 5 m from the finishing line) between runs until exhaustion. Running speeds were dictated by an audible cue played from a CD (Castagna *et al.*, 2005b). If the participant failed twice to reach the cones or the 20 m line in time, they would immediately be withdrawn from the test. To ensure that the referees gave a maximal effort, verbal encouragement was given during the test. The total distance covered during the YYIR level one test was measured. The following equation was used to estimate VO_{2max}:

VO_{2max} (ml/min/kg) (Bangsbo *et al.*, 2008)

$$= \text{YYIR distance (m)} \times 0.0084 + 36.4$$

As soon as the referee completed the YYIR level one, the heart rate monitor was stopped and the data was downloaded. The referees were immediately taken to the station next to the football pitch to complete the Stroop task. The YYIR level one test was used as a model of induced physical fatigue. Referees were encouraged to cool down after the tests.

Cognitive function test

The research team visited the referees in their home towns for the Stroop task, change of direction test and YYIR level one test. All these tests were carried out at the football field. Tests were carried out early in the morning or late in the afternoon to limit the effect of warm weather conditions on their performance. All the participants had to warm up for ten minutes. The warm up involved jogging, dynamic stretching and sub maximal sprints.

The cognitive function test (modified Stroop task) was administered twice. The participants completed the first test (pre-exhaustion) before the warm up and the second test (post-exhaustion) immediately after the YYIR level one test.

The modified Stroop task

Purpose: The modified Stroop task is used to evaluate selective attention, executive abilities and ability to inhibit habitual response (Gruber *et al*., 2002; Chang & Etnier, 2009).

Procedure: The modified Stroop task is a computer-based task that was used to assess the cognitive function of the referees in both a rested state and after a fatigue-induced protocol (the YYIR level one test). The task was presented in English and the verbal instructions about the task were given in English, Ndebele or Shona. All the participants of the study were competent in using a computer. The researcher demonstrated and explained the task stage by stage. This was followed by the participants completing the task under supervision of the researcher who made sure that the participant understood how to perform the task. They were given a final familiarisation trial without correction by the researcher.

When performing the task, decisions need to be made depending on the stimuli. The cognitive functioning of an individual during the task requires the process of attention. The individual needs to selectively concentrate on specific stimuli and at the same time ignore the irrelevant or less important stimuli (Gruber *et al*., 2002). When attention is divided, it means there is interference. The test requires an automatic process when naming the words and a consciously controlled process when naming the colours. The modified Stroop task was programmed using Java (TM) (Platform SE 7 U21 binary) and was loaded onto two laptops (HP model 635) to allow testing in the field.

At the beginning of the Stroop task and at each level of the test an instruction would appear on the screen for 30 s (see Figure 3.2). The participants had to respond after receiving a command at the beginning of each level. The stimulus was presented on the centre of the laptop screen with the two responses situated at the bottom left and right of the screen. The participant pressed either the (<) or (>) key on the keyboard which would correspond to the left and right response when responding to the stimulus. Participates were requested to use their right hand when selecting their answers.

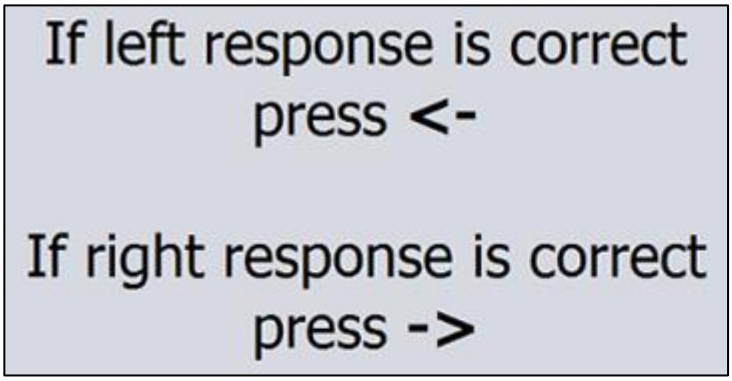


Fig. 3.2. Instructions at the beginning of the Stroop task

Four levels (with increasing difficulty) of the modified Stroop task were used and there were 24 trials at each level. The four levels were: word naming (condition one - C_1), colour naming (condition two - C_2), colour and word naming (naming the text colour – when colour and word are incongruent) (condition three - C_3) and mixed colour and word naming and answer (condition four - C_4). Examples of the four conditions are shown in Figure 3.3.

The original Stroop colour – word test was first studied and published by John Ridley Stroop in 1935 (Lemercier, 2009). The Stroop task requires the participant to identify and read out the text colour of a word, for example if the word BLUE is printed in the same colour blue it is said to be congruent and when the word BLUE is printed in the a conflicting colour like red it is said to be incongruent. In the modified Stroop task, the first level (C_1) contains a word typed in black colour and participants were required to show their ability to name the word by choosing the correct answer. The second level of the task (C_2) required participants to choose the correct colour of the block shown in the middle of the screen. In the third level (C_3), the word was presented in a conflicting colour and the answers were presented in black. The participant was required to describe the ink colour of the word to show if they were able to suppress irrelevant stimuli. During the fourth level (C_4), the middle word was presented in a conflicting colour, whilst the answers were also presented in a conflicting colour and participants were expected to choose the word that describes the colour of the middle word.

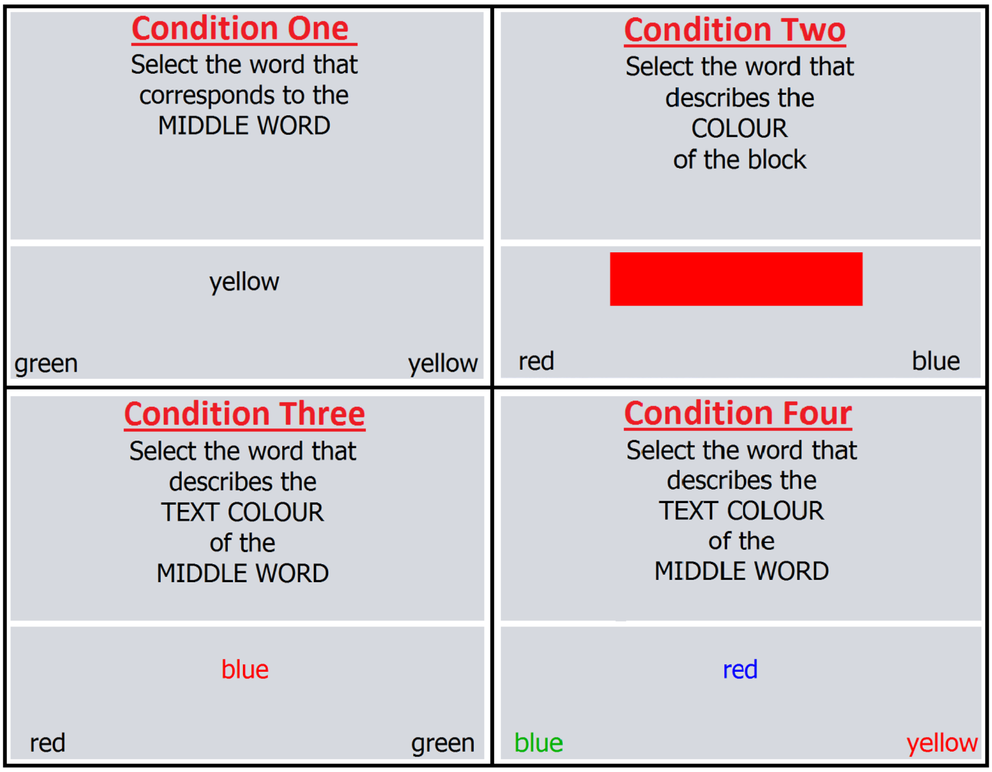


Fig. 3.3. Visual illustration of the four modified Stroop Task conditions

The tasks did not have any time limit as it was self-determined by the response time to each stimulus. Both reaction time and accuracy of given answers were measured. The results of each completed task was downloaded and saved for analysis on a Microsoft Excel spreadsheet. The scores for conditions one and two were used to measure the processing, while condition three and four were used to measure interference or “The Stroop effect” (Van der Elst *et al.*, 2013). The interference score was calculated by subtracting the time for C_3 from the time for C_2. The same four blocks were administered before and immediately after completing the CODA test and the YYIR level one test.

Heart rate

The heart rates of the referees were monitored during the YYIR level one test using Garmin FR70 (Taiwan) heart rate monitors. At the end of the YYIR level one test the heart rate data was downloaded using Garmin online software and the maximum heart rate (HR_{max}) was used for subsequent analysis.

Various equations have been developed to predict HR_{max}. Londeree and Moeschberger (1982) came up with an equation that attempted to address issues of race, age, gender and level of fitness in predicting the HR_{max} of different individuals. They concluded that there was a decline in the HR_{max} with age, but that HR_{max} was not confounded by sex or race. Their study was carried out among the general population who were between the ages of 5 and 81 years and did not consider the participant's body mass or physical fitness levels. In the study by Miller *et al.* (1993) the participants were involved in fitness programmes. They were divided into two groups; obese individuals and normal weight individuals. Their mean age was 42.0 ± 1.0 years and 45.3 ± 1.8 years, respectively. Results suggested that the equation: 217 – (0.85 x age) was more suitable for predicting HR_{max} for people involved in fitness programmes. The equation by Miller *et al.* (1993) was, therefore, used in this study to calculate the predicated HR_{max}.

Data analysis

The measurement of precision and reliability of the kinanthropometric measures was calculated using the technical error of measurements (TEM) and intraclass correlation coefficients (ICC) using the following equations:

$$TEM\ (absolute) = \sqrt{MSe}$$

Where: MSe = mean square error (that is ($\frac{\sum d_1^2}{2n}$) summing the squared differences d_1 between test and retest for each person (i) divided by two times the sample size (n) (Eston et al., 1996)

$$\%TEM\ (relative) = \frac{TEM}{Mean} \times 100$$

Where: Mean = overall mean of the variable or sample mean score

The intraclass correlation coefficient (ICC) was used to show the correlation among the three measurements taken on the same subject. The ICC was used to indicate the reliability and close agreement of measurements. The measurement was considered highly reliable when the value was close to 1 between values range of 0 to 1. To attain ICC scores in the current study the mean squares from analysis of variance of measurements were combined in a ratio formula (Norton & Olds, 1996) and computed on the ISAK Microsoft Excel spread sheet.

The four physical fitness performance variables; vertical jump, YYIR indirect VO_{2max}, 6 x 40 m RSA and CODA were combined and used to calculate the mean *z*-score. Each of these variables contributed equally to the standardised physical fitness performance score which was correlated with the cognitive function (Stroop test) results. The formula described by Thomas and Nelson (2001) was used to calculate the z-score for each variable:

$$Standardized\ \text{score (z)} = \frac{X - M}{s}$$

Where: X =sample value

M =sample mean

s = standard deviation

All statistical analysis was performed using the STATISTICA data software programme Version 12 and Microsoft Office Excel 2013. Descriptive statistics (means (M) and standard deviations (SD)) were calculated to summarize the anthropometric and physical fitness performance data. Statistical significance was set at $p \leq .05$, unless otherwise stated.

A one way analysis of variance (ANOVA) was used to compare the FIFA and ZIFA referees, as well as the referees and assistant referees on all the variables. ANOVA's were also used in the pretest-posttest comparisons for the Stroop task. Spearman rank order correlation coefficients were calculated to determine the relationships between age and the various body composition variables, as well as between the cognitive functioning variables and the physical fitness performance scores. The size of the Spearman correlation coefficients (r) was interpreted according to the recommendations by Thomas and Nelson (2001) shown below.

Table 3.3. Interpretation of the Spearman coefficient correlations (r).

r	Interpretation
0.00 – 0.19	Very weak
0.20 – 0.39	Weak
0.40 – 0.59	Moderate
0.60 – 0.79	Strong
0.80 – 1.0	Very Strong

Effect sizes (ES) were calculated (for demographic, body composition, physical fitness and cognitive functioning data) using the formula described by Thomas and Nelson (2001).

$$Effect\ size\ (ES) = \frac{M_1 - M_2}{s}$$

Where: M_1 *= group one mean*
M_2 *= group two mean,*
S = standard deviation.

The pooled standard deviation was calculated according to the following formula:

$$Sp = \sqrt{\frac{S1^2(n1-1)+S2^2(n2-1)}{n1+n2-2}}$$

When: *S1 = variance of the participants in Group One*
n1 = number of participants in the first group
S2 = variance of the participants in Group Two
n2 = number of participants in the second group

The effect sizes were interpreted according to the guidelines by Thomas and Nelson (2001) as shown in Table 3.4.

Table 3.4. Interpretation of the effect size magnitude (d).

Effect Size (d)	Interpretation
More or less 0.8	Large
More or less 0.5	Moderate
More or less 0.2	Small

Chapter 4
Results

Introduction

This chapter presents the anthropometric and physical profiles, as well as the cognitive functioning results of elite Zimbabwean football referees. The first section presents the referees' demographic information, educational background, refereeing experience and training history. This is followed by a comparison of the anthropometric and physical characteristics between elite FIFA and ZIFA referees, as well as between the referees and assistant referees. Thereafter, the pre- and post-intervention cognitive functioning of the total group of referees is compared. Finally, the relationship between cognitive functioning and the physical fitness levels of elite Zimbabwean referees is reported.

Participants

A total of 41 participants met the inclusion criteria and voluntarily participated in the study. The sample consisted of 21 referees and 20 assistant referees. Eight of the participants (three referees and five assistant referees) were FIFA licensed referees, whereas the remaining 33 officiated in the ZIFA premier league. Three of the participants did not take part in the second phase of the study due to other commitments.

Demographic variables

Table 4.1 depicts the demographic data, highest qualification, refereeing experience and training history of elite Zimbabwean football referees. There were no significant age differences between the respective groups. The results showed that all the referees had at least completed Ordinary Level which implies that they can read and write. Six of the referees had Bachelor's degrees, with a further three holding Master's degrees. The FIFA referees had statistically significantly more years of refereeing in the Zimbabwean Premier Soccer League (PSL) or ZIFA license than the ZIFA referees ($p = .01$). There was no difference in the number of training sessions per week between the various groups of referees.

Table 4.1. Demographic, Education, Refereeing Experience and Training history of the elite Zimbabwean Football referees (N = 41).

	Total group (N = 41)	FIFA (n = 8)	ZIFA (n = 33)	Significant differences		Referees (n = 21)	Assistant Referees (n = 20)	Significant differences	
	M ± SD	M ± SD	M ± SD	p	ES	M ± SD	M ± SD	p	ES
Study participants (%)	100.0	19.51	80.49	-	-	51.22	48.78	-	-
Age (years)	34.89 ± 5.13	34.20 ± 4.22	35.06 ± 5.38	.68	0.17	35.00 ± 5.56	34.77 ± 4.79	.89	0.04
Highest Educational Level									
'O' Level	n = 16	n = 3	n = 13	-	-	n = 6	n = 10	-	-
Certificate	n = 1	-	n = 1	-	-	-	n = 1	-	-
Diploma	n = 15	n = 4	n = 11	-	-	n = 9	n = 6	-	-
Degree	n = 6	n = 1	n = 5	-	-	n = 4	n = 2	-	-
Masters	n = 3	-	n = 3	-	-	n = 2	n = 1	-	-
Refereeing experience									
Years refereeing	10.85 ± 3.85	12.75 ± 3.54	10.39 ± 3.83	.12	0.62[a]	11.19 ± 3.87	10.50 ± 3.90	.57	0.18
Years with ZIFA license	4.02 ± 2.54	6.25 ± 2.66	3.48 ± 2.24	.01**	1.19[b]	4.19 ± 2.44	3.85 ± 2.70	.67	0.13
Years with FIFA license		3.00 ± 1.20	-	-	-	3.67 ± 0.58 (n = 3)	2.60 ± 1.34 (n = 5)	.25	0.94[b]
Number of international matches		9.75 ± 6.58	-	-	-	15.00 ± 7.55 (n = 3)	6.60 ± 3.78 (n = 5)	.07	1.57[b]
International matches per year		2.80 ± 1.10	-	-	-	3.00 ± 1.41 (n = 2)	2.67 ± 1.15 (n = 3)	.79	0.27
Matches per month	2.73 ± 0.92	3.38 ± 1.19	2.58 ± 0.79	.03*	0.91[b]	2.76 ± 0.62	2.70 ± 1.17	.83	0.07
PSL matches per year	15.00 ± 8.84	20.13 ± 4.36	13.76 ± 9.24	.07	0.74[b]	15.76 ± 8.41	14.20 ± 9.42	.58	0.18
Training sessions									
Training sessions per week	3.51 ± 0.75	3.63 ± 0.52	3.48 ± 0.80	.64	0.19	3.52 ± 0.68	3.50 ± 0.83	.92	0.03

* Statistically significant difference ($p \leq .05$) ** Statistically significant difference ($p \leq .01$)
a Moderate practical significant difference ($d \approx 0.5$) b Large practical significant difference ($d \approx 0.8$)

Figure 4.1 shows the age distribution of the total group, FIFA referees, ZIFA referees, referees and assistant referees, respectively. The results show that 50% of the FIFA referees were younger than 32 years and there was a smaller variation in the age range of the FIFA referees compared to the other groups of referees. Among the ZIFA referees the boxplot showed that the age of referees were fairly equally spread around the mean age of 35 years and it showed that there was a greater variation between the youngest and the oldest referee in the group. The median age of the referees and assistant referees were similar at around 33 years, however, the variation of age among the referees was larger than that of the assistant referees. A positive skewedness was observed among the assistant referees meaning that the sample included a large number of young assistant referees.

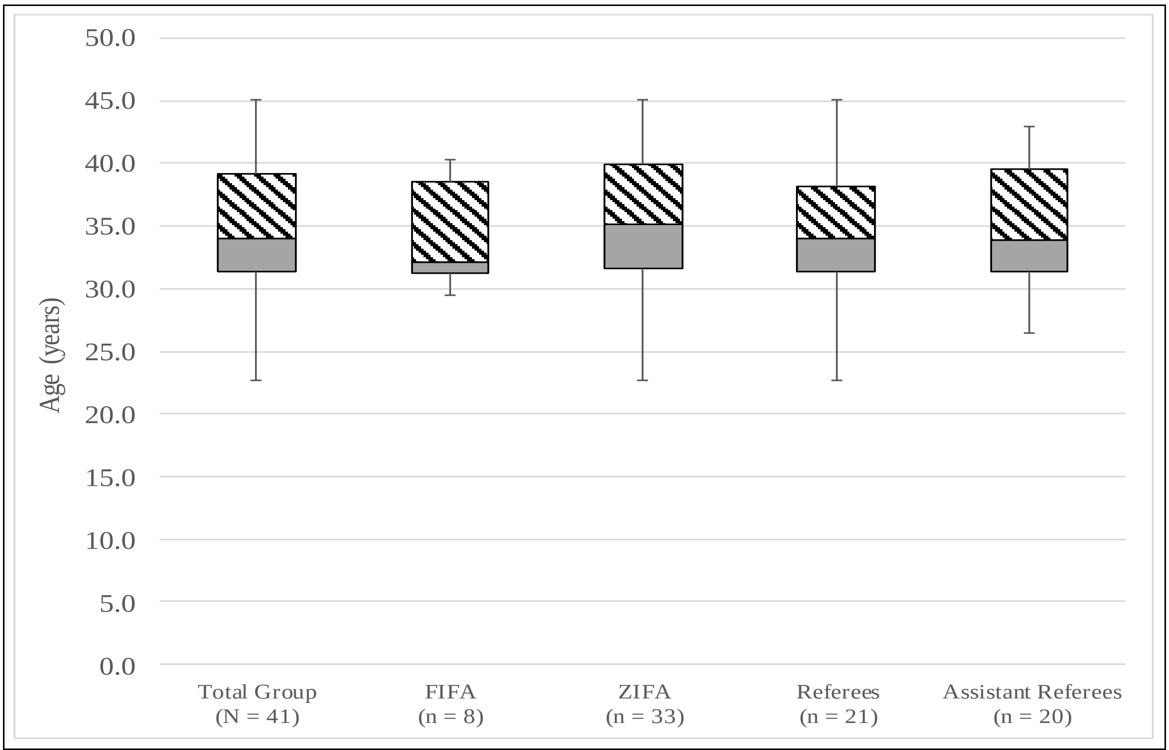


Fig. 4.1. Boxplots depicting the age of the elite Zimbabwean Football Referees (N = 41)

Figure 4.2 shows the boxplots for the number of refereeing years of the elite Zimbabwean referees. The results showed that most of the FIFA referees had less than 13 years of refereeing experience, but they had more years of refereeing experience compared to all the other groups. The boxplot was symmetric, while the distribution of the data was positively skewed with a small variation with regard to the years of refereeing experience among the FIFA referees. Despite the fact that both the referees and assistance referees' data was negatively skewed, the results showed that most referees had more years of refereeing experience than the assistant referees. The referees were tightly grouped between the median

(12 years) and the upper quartile (13 years) compared to the assistant referees who were spread between the median (10 years) and upper quartile (13 years).

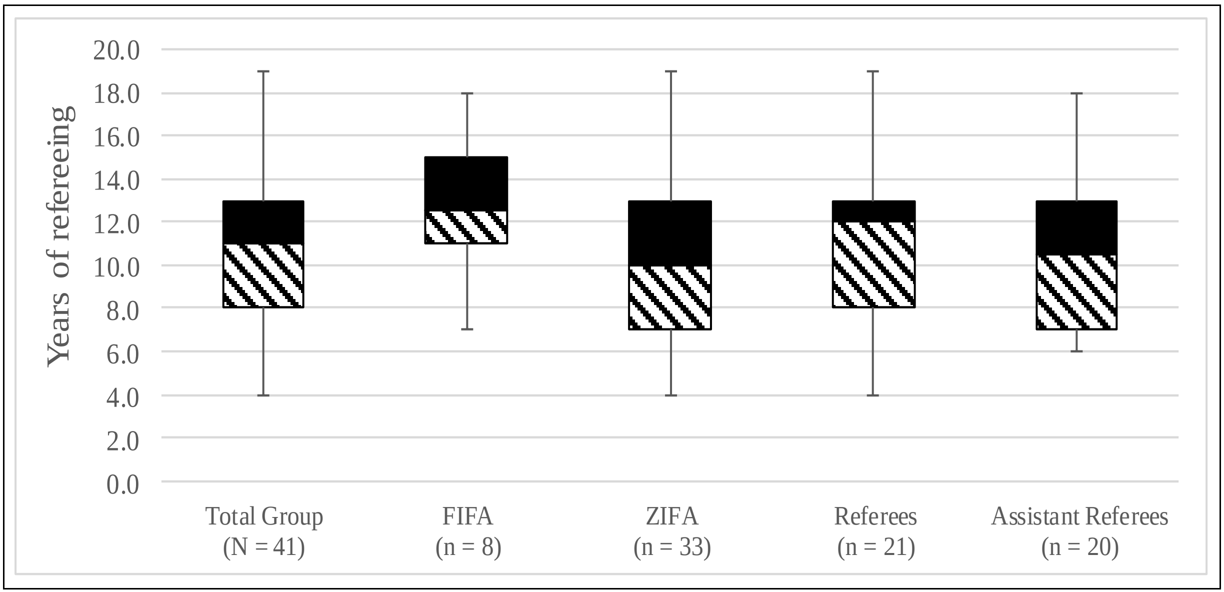


Fig. 4.2. Boxplots depicting the years of refereeing of the elite Zimbabwean Football Referees (N = 41)

Figure 4.3 shows that the FIFA referees officiated in significantly ($p = .03$) more matches per month than the ZIFA referees. Most referees officiated between two and three games per month. The results also show that the FIFA referees had officiated in statistically significantly more games than their ZIFA counterparts. Furthermore, FIFA referees officiated in more games per year compared to the rest of the groups (see Figure 4.4).

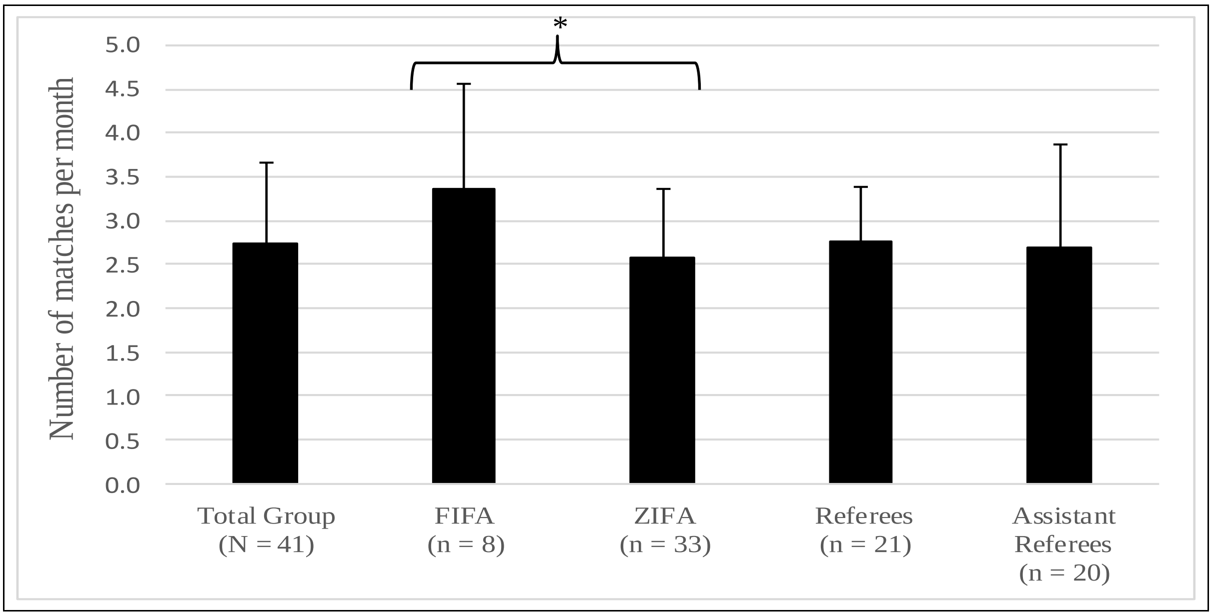


Fig. 4.3. Bar graphs depicting the number (± SD) of Zimbabwean Premier League matches per month in which the referees (N = 41) officiated

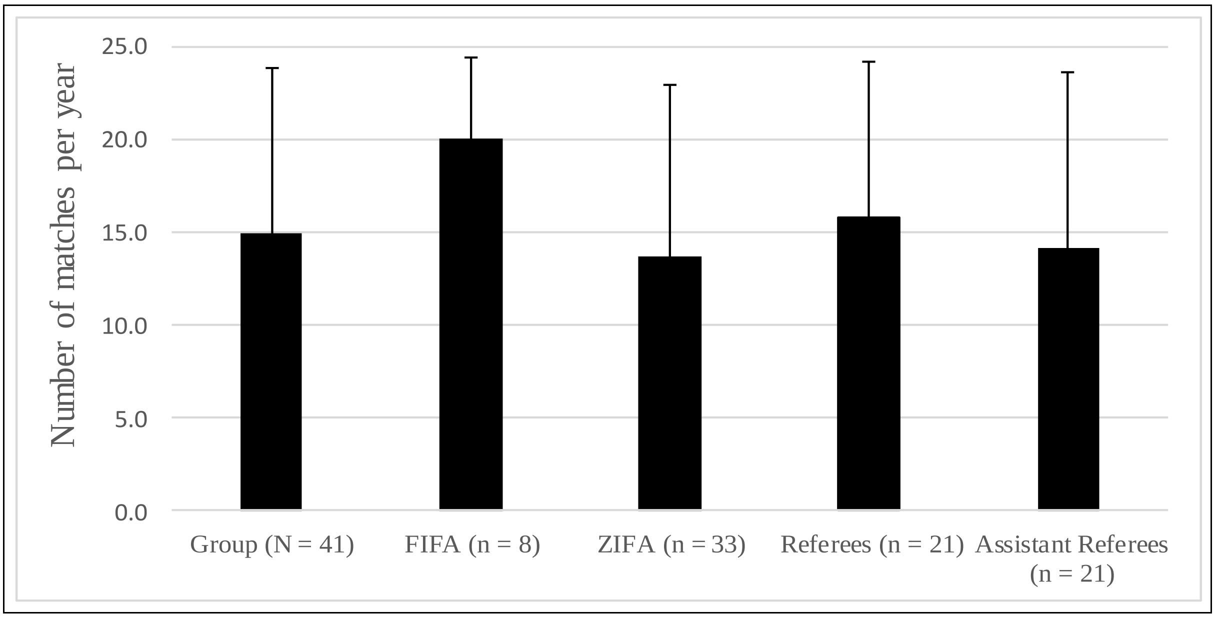


Fig. 4.4. Bar graphs depicting the number (± SD) of Zimbabwean Premier League matches per year in which the referees (N = 41) officiated

Body Composition

Table 4.2 depicts the technical error of measurements (TEM) for the precision of measurements and the intraclass correlation coefficients (ICC) for the reliability in the body composition measurements. ISAK recommends a maximum technical error of measurement for level two anthropometrists of 5 % for skinfolds and 1 % for other measurements like circumferences and bone breaths. The results show that the TEM and ICC were all within the target percentage and that the testers' measurements were reliable.

Table 4.2. The Technical Error of Measurement (TEM) and Intraclass Correlation Coefficients (ICC).

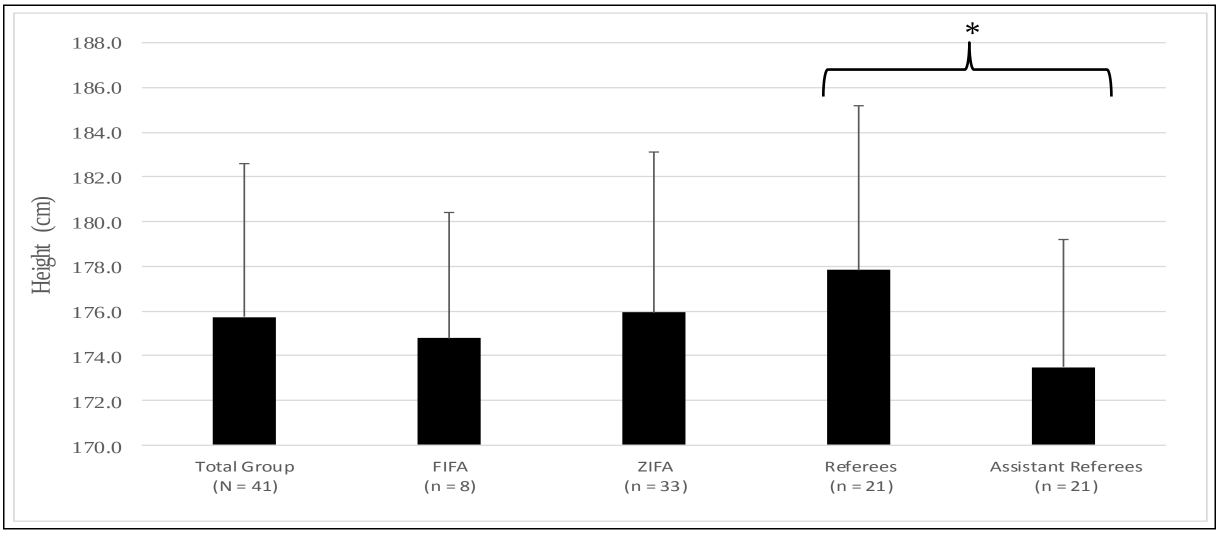
	TEM Intra		ICC
	Value	%	
Body mass	0.06	0.08	1.00
Stature	0.13	0.08	1.00
Triceps skinfold	0.13	1.56	1.00
Subscapular skinfold	0.22	1.97	1.00
Supraspinale skinfold	0.24	3.15	1.00
Abdominal skinfold	0.41	2.93	1.00
Front thigh skinfold	0.31	2.60	1.00
Medial calf skinfold	0.19	2.30	1.00
Arm girth (relaxed)	0.16	0.67	1.00
Arm girth (flexed & tensed)	0.19	0.63	0.99
Waist girth (min)	0.56	0.76	0.99
Gluteal girth (max)	0.80	0.86	0.98
Calf girth (max)	0.07	0.20	1.00
Humerus breadth (biepicondylar)	0.02	0.26	1.00
Femur breadth (biepicondylar)	0.03	0.31	1.00

Table 4.3 illustrates the body composition results of the elite Zimbabwean referees, with a comparison between the FIFA and ZIFA referees, as well as between the referees and assistant referees. No significant differences were observed in the body composition variables except for the height of the referees and assistant referees ($p = .04$). Figure 4.5 shows that the referees were taller than the assistant referees. A moderate practical significant difference was observed between the FIFA and ZIFA referees' body mass, BMI, endomorphy and mesomorphy. A similar moderate practical significant difference was observed between the referees and assistant referees for height and mesomorphy.

Table 4.3. Body composition results of the elite Zimbabwean Football Referees (N = 41).

	Group (N= 41)	FIFA (n = 8)	ZIFA (n = 33)	Significant differences		Referee (n = 21	Assistant Referee (n = 20)	Significant differences	
	M ± SD	M ± SD	M ± SD	p	ES	M ± SD	M ± SD	p	ES
Body Mass (kg)	70.52 ± 10.50	67.06 ± 7.48	71.36 ± 11.04	.30	0.41[a]	71.83 ± 11.57	69.16 ± 9.34	.42	0.25
Height (cm)	175.72 ± 6.86	174.79 ± 5.62	175.95 ± 7.18	.67	0.17	177.85 ± 7.32	173.50 ± 5.69	.04*	0.66[a]
Body Mass Index (kg/m^2)	20.79 ± 2.47	19.92 ± 1.64	21.00 ± 2.61	.27	0.44[a]	20.86 ± 2.72	20.72 ± 2.24	.86	0.06
Waist to Hip Ratio	0.83 ± 0.04	0.83 ± 0.04	0.82 ± 0.04	.65	0.18	0.82 ± 0.05	0.83 ± 0.03	.43	0.25
Sum of 6 Skinfolds (mm)	65.77 ± 24.75	59.89 ± 16.55	67.20 ± 26.36	.46	0.29	68.31 ± 26.33	63.11 ± 23.35	.51	0.21
% BF (Reilly *et al.*, 2009)	11.97 ± 2.60	11.53 ± 1.89	12.07 ± 2.76	.60	0.21	12.23 ± 2.64	11.69 ± 2.61	.51	0.21
Endomorphy	2.68 ± 1.19	2.24 ± 0.65	2.78 ± 1.27	.25	0.46[a]	2.71 ± 1.27	2.64 ± 1.12	.83	0.07
Mesomorphy	4.62 ± 0.84	4.34 ± 0.63	4.69 ± 0.87	.29	0.43[a]	4.43 ± 0.69	4.83 ± 0.94	.13	0.49[a]
Ectomorphy	2.65 ± 1.07	2.98 ± 0.75	2.58 ± 1.13	.35	0.37	2.85 ± 1.14	2.45 ± 0.97	.23	0.38

* Statistically significant difference ($p \leq .05$)
[a] Moderate practical significant difference ($d \approx 0.5$)
Sum of 6 Skinfolds (cm) (triceps, subscapular, iliac crest, abdominal, front thigh and medial calf)



* Statistical significant differences (p ≤ .05)

Fig. 4.5. Bar graphs depicting the mean (± SD) height of the elite Zimbabwean Football Referees (N = 41)

Somatotype

Figure 4.6 show the individual and mean somatoplots as well as the category chart for the elite Zimbabwean referees. The referees were balanced mesomorphs (mean 2.62-4.65-2.65 ± 2.24-4.34-2.98). A dominancy of the mesomorphy component was observed among elite Zimbabwean referees indicating that Zimbabwean referees tend to be muscular. The FIFA referees were ectomorphic-mesomorphs, while the ZIFA referees were endomorphic-mesomorphs. Likewise, the referees were ectomorphic-mesomorphs, whilst assistant referees were endomorphic-mesomorphs. There was no difference between the groups (FIFA and ZIFA referees; p = .30) or between the referees and assistant referees (p = .31) as shown in Figure 4.8 and Figure 4.10, respectively.

The category charts contain a summary of the percentage players in each of the 13 somatotype categories. The participants of the study could be categorized into eight categories, with three of these categories only having one participant, whilst the majority of the participants were spread around the remaining five categories as shown in Figure 4.7. Fourteen referees (34 %) fell in category six (i.e., endomorphic-mesomorphs).

Figures 4.9 and 4.11, respectively, show the category charts of the FIFA and ZIFA referees, as well as the referees and assistant referees. Among the FIFA referees, the most prevalent category (category 9; mesomorph-ectomorph) contained 38 % of the sample and the rest were spread across four categories. The ZIFA referees fell into eight categories and the largest category (category 6; endomorphic-mesomorph) contained 36 % of the sample. Figure 4.11 shows that category 8 (i.e., ectomorphic-mesomorphs) included the majority of the referees, whilst the majority of the assistant referees fell in category 6 (i.e., endomorphic-mesomorphs).

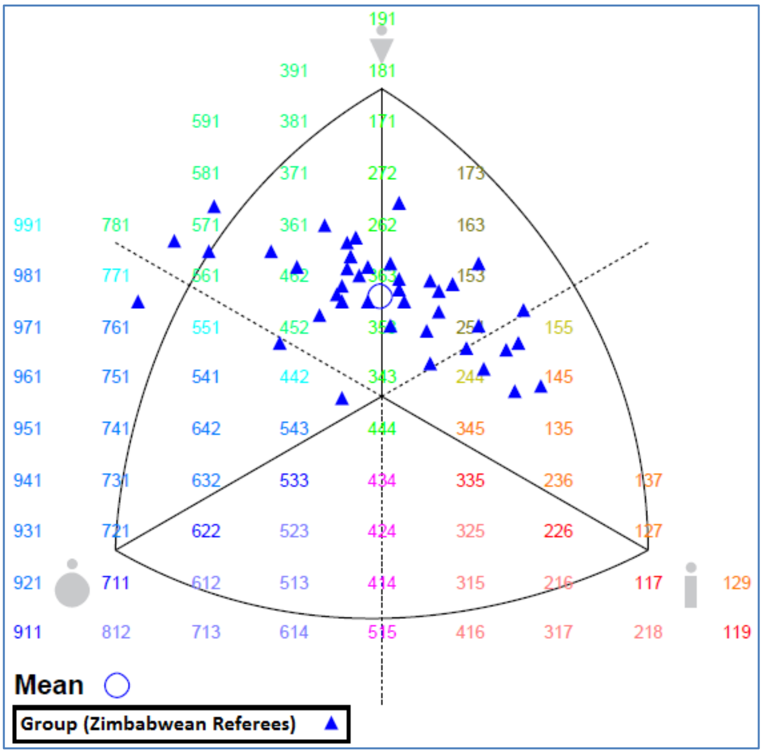


Fig. 4.6. Somatochart showing the individual and mean somatoplots for the elite Zimbabwean referees (N = 41; 2.68-4.62-2.65 = balanced mesomorphs)

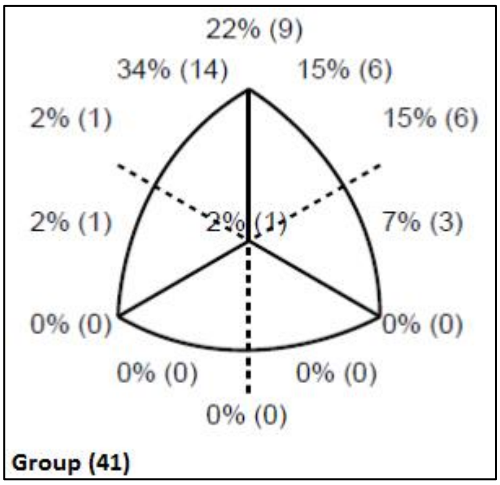


Fig. 4.7. Somatotype category chart of the elite Zimbabwean referees (N = 41)

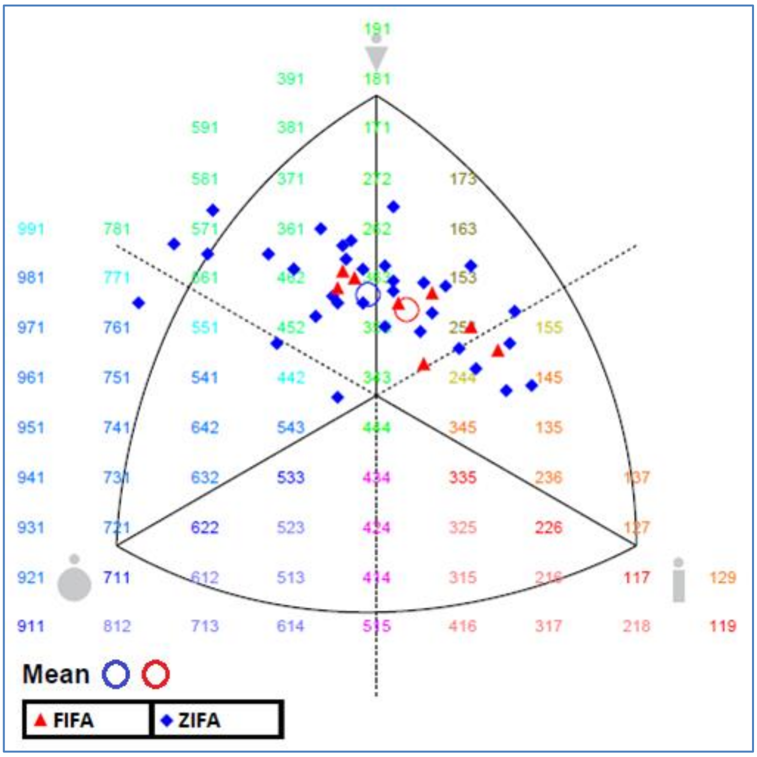


Fig. 4.8. Somatochart showing the individual and mean somatoplots for FIFA referees (n = 8; 2.24-4.34-2.98, ectomorphic-mesomorphs) and ZIFA referees (n = 33; 2.78-4.69-2.58, endomorphic-mesomorphs)

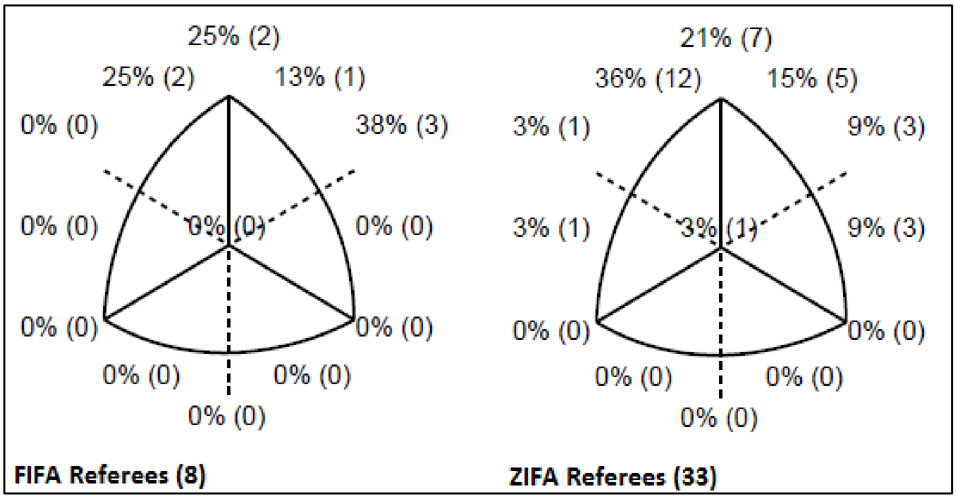


Fig. 4.9. Somatotype category chart for FIFA referees (n = 8) and ZIFA referees (n = 33)

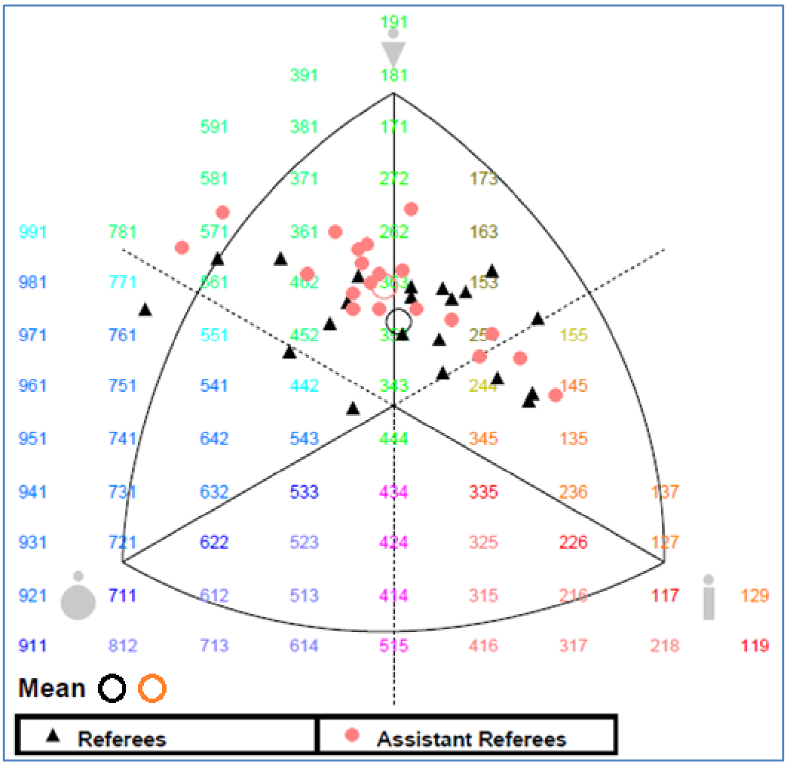


Fig. 4.10. Somatochart for Referees (n = 21) (2.71-4.43-2.85, ectomorphic-mesomorphs) and Assistant Referees (n = 20) (2.64-4.83-2.45, endomorphic-mesomorphs)

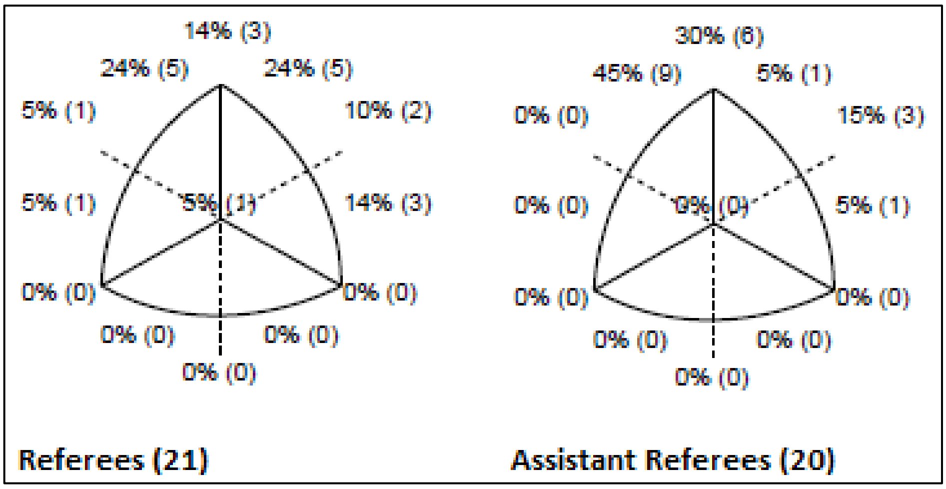


Fig. 4.11. Somatotype category chart for referees (n = 21) and assistant referees (n = 20)

The relationship between age and the various body composition variables

The results showed a moderate statistically significant linear relationship between the following variables: age and waist-hip ratio (r = 0.50, p = .01), as well as age and BMI (r = 0.34, p = .04) (see Table 4.4). However, since there were no age differences between the respective groups (FIFA vs. ZIFA, and Referees vs. Assistant referees), age was not used as a covariant in any of the subsequent analysis.

Table 4.4. Correlations between age and the various body composition variables among elite Zimbabwean Football Referees (N = 41).

	Spearman correlation (r)	Statistical significance (p)
Body mass (kg)	0.27	.09
Height (cm)	0.07	.67
Body Mass Index (kg/m^2)	0.32	.04*
Waist to Hip Ratio	0.50	.01**
Sum of 6 Skinfolds (mm)	0.19	.23
% BF (Reilly *et al.*, 2009)	0.21	.19
Endomorphy	0.27	.08
Mesomorphy	0.21	.18
Ectomorphy	0.30	.06

* Statistically significant difference ($p \leq .05$) ** Statistically significant difference ($p \leq .01$)
Sum of 6 Skinfolds (mm) (triceps, subscapular, supraspinal, abdominal, front thigh and medial calf)

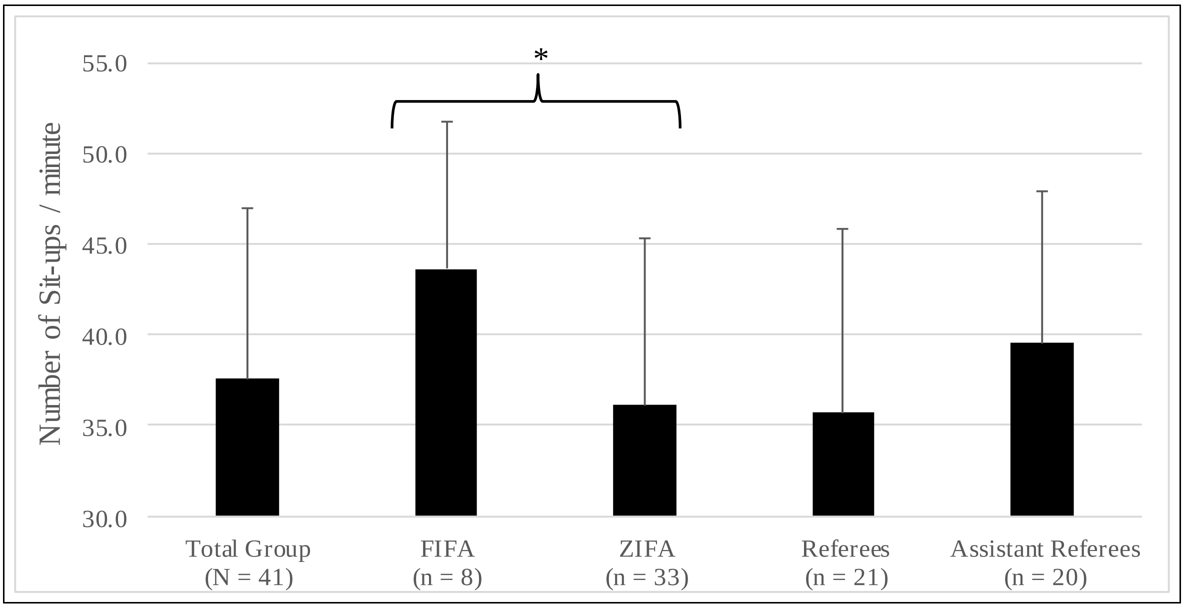
Physical fitness

Table 4.5 contains the physical fitness results of the elite Zimbabwean football referees. There was missing data for two participants for the one minute push-up test, the CODA test and the YYIR level one test. The FIFA referees performed a significantly greater number of sit ups in one minute than the ZIFA referees ($p = .04$). In the 6 x 40 m RSA test, the best 40 m time of the FIFA referees were significantly faster than that of the ZIFA referees ($p = .03$, $d = 0.88$). There were no statistically significant differences observed in any of the other physical fitness variables. Moderate practical significant differences were observed between the FIFA referees and ZIFA referees and between the referees and assistant referees for the one minute sit up test. A large practical significant difference was also observed between the FIFA referees and ZIFA referees in the following physical fitness variables: vertical jump test, one minute sit up test, one minute push up test and mean time on the 6 x 40 m RSA test. The bar graphs in Figure 4.12 shows that the FIFA referees performed significantly better ($p < .04$, $ES = 0.83$) than ZIFA referees, whilst the assistant referees performed better than referees in the one minute sit-up test. Figure 4.13 reflects that the FIFA referees had faster trial times than the ZIFA referees in the 6 x 40 m RSA test.

Table 4.5. Physical fitness results of the elite Zimbabwean Football Referees (N = 41).

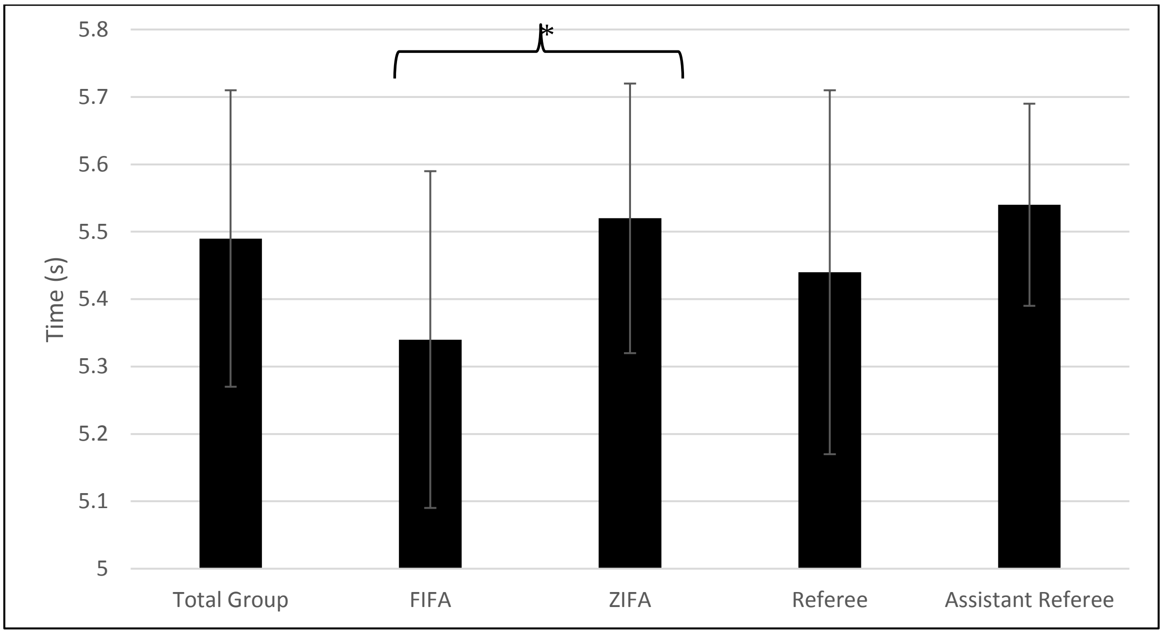
	Group (N = 41)	FIFA (n = 8)	ZIFA (n = 33)	Significant differences		Referees (n = 21)	Assistant Referees (n = 20)	Significant differences	
	M ± SD	M ± SD	M ± SD	P	ES	M ± SD	M ± SD	p	ES
Modified Sit and Reach (cm)	28.31 ± 6.42	29.49 ± 4.89	28.02 ± 6.77	.57	0.23	29.38 ± 6.14	27.18 ± 6.66	.28	0.34
Vertical Jump (cm)	38.63 ± 5.63	41.8 1± 5.92	37.92 ± 5.37	.08	0.71[b]	38.76 ± 5.56	38.60 ± 5.84	.93	0.03
One Minute Sit-up	37.56 ± 9.46	43.63 ± 8.18	36.09 ± 9.26	.04*	0.83[b]	35.67 ± 10.22	39.55 ± 8.38	.19	0.41[a]
One Minute Push-up#	26.13± 6.89	30.00 ± 7.73	25.13 ± 6.42 (n = 31)	.07	0.73[b]	26 ± 7.94 (n = 19)	26.25 ± 5.94	.91	0.04
6 x 40m Sprint Repeated Ability (SRA) – Best time (s)	5.49 ± 0.22	5.34 ± 0.25	5.52 ± 0.20	.03*	0.88[b]	5.44 ± 0.27	5.54 ± 0.15	.14	0.47[a]
6 x 40m Sprint Repeated Ability – (SRA) – Mean time (s)	5.62 ± 0.19	5.51 ± 0.21	5.65 ± 0.18	.06	0.75[b]	5.59 ± 0.23	5.65 ± 0.14	.36	0.29
Change of Direction (CODA) – Best time (s)#	9.60 ± 0.42 (n = 39)	9.40 ± 0.20 (n = 6)	9.64 ± 0.44	.20	0.58[a]	9.53 ± 0.42 (n = 20)	9.67 ± 0.41 (n = 18)	.28	0.35
YYIR level one (meters)#	950 ± 279 (n = 39)	980 ± 439 (n = 6)	944 ± 250	.78	0.13	940 ± 235 (n = 20)	958 ± 318 (n = 18)	.84	0.06
YYIR level one Indirect VO_{2max} (ml/min/kg)#	44.38 ± 2.35 (n = 39)	44.63 ± 3.69 (n = 6)	44.33 ± 2.10	.78	0.13	44.45 ± 2.67 (n = 20)	44.30 ± 1.97 (n = 18)	.84	0.06

Missing data
* Statistically significant difference ($p \leq .05$)
[a] Moderate practical significant difference ($d \approx 0.5$) [b] Large practical significant difference ($ES \approx 0.8$)



* Statistically significant difference (p ≤ .05)

Fig. 4.12. Bar graphs depicting the mean (± SD) results for the one minute sit-up test among the elite Zimbabwean Football Referees (N = 41)



* Statistical significant differences (p ≤ .05)

Fig. 4.13. Bar graphs depicting the mean (± SD) results for the best trial during the 40m RSA test among the elite Zimbabwean Football Referees (N = 41)

Cognitive function

A total of 38 participants completed the Stroop task before and after they completed a 10 minute warm up, the CODA and YYIR tests. There were no interaction effect between association (FIFA or ZIFA) and referee type (referees or assistant referees) over time. This implies that the change over time (before and after the physical exertion) was the same in all the groups and, therefore, only the pre to post-test comparison for the total group will be reported. Table 4.6 reports the correlations between the number of correct answers (percentage) and the total time taken at each level, with Table 4.7 and 4.8, containing the pre and post-test relationships between these variables.

The pre-test results presented in Table 4.8 revealed a significant correlation ($r = 0.32$, $p = .05$) for C_3 only. The relationship between the number of correct answers and time to complete at C_4 was almost significant ($r = 0.31$, $p = .06$). This suggests that taking longer to complete the task was associated with a higher success rate. The post-test results only revealed a moderate significant relationship for C_1 ($r = 0.41$, $p = .01$). Again these results indicate that the referees who scored a high percentage of correct answers took more time to complete this level.

Pre- to post-test comparisons and percentage change on the Stroop task

The percentage of correct answers and total time for each level of the Stroop task for the pre- and post-exercise test were compared (see Table 4.9 and Figures 4.14 to 4.17). Figure 4.14 show that there was not much change in the number of correct answers from pre- to post-test for C_1 and C_2. The post-test results of C_3 shown in Figure 4.15 indicate that a number of the referees made more errors compared to their pre-test scores. A small improvement was observed in the number of referees who improved in their performance (percentage correct answers) from pre to post-test during C_4 as illustrated by the shorter whisker as shown in Figure 4.15. The pre to post-test percentage changes for each condition were calculated and presented in the same table. The interference score was also calculated and reported in the table by subtracting the time for C_2 from the time for C_3. A statistically significant improvement in the total times were observed from pre-test to post-test for C_1 ($p = .01$), C_2 ($p = .01$) and C_3 ($p = .04$). The improvement observed during C_4 bordered on being statistically significant ($p = .06$). There were no significant differences between the pre- to post-test percentage correct answers or the pre- to post-test interference scores.

Table 4.6. The relationship between the number of correct answers (%) and the total time (s) on the Stroop task (n = 38).

	Spearman correlation (r)	Statistical significance (p-value)
C1 - Word reading	0.22	.05*
C2 - Colour naming	0.01	.90
C3 - Colour and Word naming	0.08	.49
C4 – Mixed Colour and Word	0.20	.09

* Statistically significant difference ($p \leq .05$)

Table 4.7. Pre-test correlations between the number of correct answers (%) and the total time (s) on the Stroop task (n = 38).

	Spearman correlation (r)	Statistical significance (p-value)
C1 - Word reading	0.08	.64
C2 - Colour naming	0.02	.89
C3 - Colour and Word naming	0.32	.05*
C4 – Mixed Colour and Word	0.31	.06

* Statistically significant difference ($p \leq .05$)

Table 4.8. Post-test correlations between the number of correct answers (%) and the total time (s) on the Stroop task (n = 38).

	Spearman correlation (r)	Statistical significance (p-value)
C1 - Word reading	0.41	.01**
C2 - Colour naming	0.07	.69
C3 - Colour and Word naming	0.10	.55
C4 – Mixed Colour and Word	0.11	.53

** Statistically significant difference ($p \leq .01$)

Table 4.9. Pre- to post-test comparisons and percentage change on the Stroop test following the fatigue-inducing protocol (n = 38).

	Pre-test (%)	Post-test (%)	Pre- to post-test change (%)	Significant differences	
	Mean ± SD	Mean ± SD	Mean ± SD	p-value	ES-value
C_1 - Word reading correctness (%)	98.79 ± 2.36	99.01 ± 2.04	0.28 ± 3.34	.67	0.10
C_1 - Word reading total time (s)	29.07 ± 8.02	25.31 ± 9.14	-12.73 ± 13.51	.01**	0.44[a]
C_2 - Colour naming correctness (%)	98.25 ± 2.49	98.36 ± 2.83	0.15 ± 3.22	.83	0.04
C_2 - Colour naming total time (s)	27.67 ± 3.13	26.15 ± 3.67	-5.48 ± 8.20	.01**	0.45[a]
C_3 - Colour and Word naming correctness (%)	96.71 ± 4.66	95.50 ± 6.00	-1.14 ± 6.38	.21	0.23
C_3 - Colour and Word naming total time (s)	42.20 ± 9.60	37.50 ± 6.52	-9.15 ± 15.20	.04*	0.57[a]
C_4 – Mixed Colour and Word correctness (%)	93.97 ± 8.26	93.53 ± 7.85	0.01 ± 9.13	.72	0.05
C_4 – Mixed Colour and Word total time (s)	51.83 ± 12.06	46.33 ± 9.92	-8.42 ± 18.01	.06	0.50[a]
Interference ($C_3 – C_2$) (s)	14.53 ± 8.03	11.35 ± 6.16	-2.59 ± 69.05 Range: -100.21 to 198.85	.28	0.44[a]

* Statistically significant difference ($p \leq .05$) ** Statistically significant difference ($p \leq .01$)
[a] Moderate practical significant difference ($d \approx 0.5$)

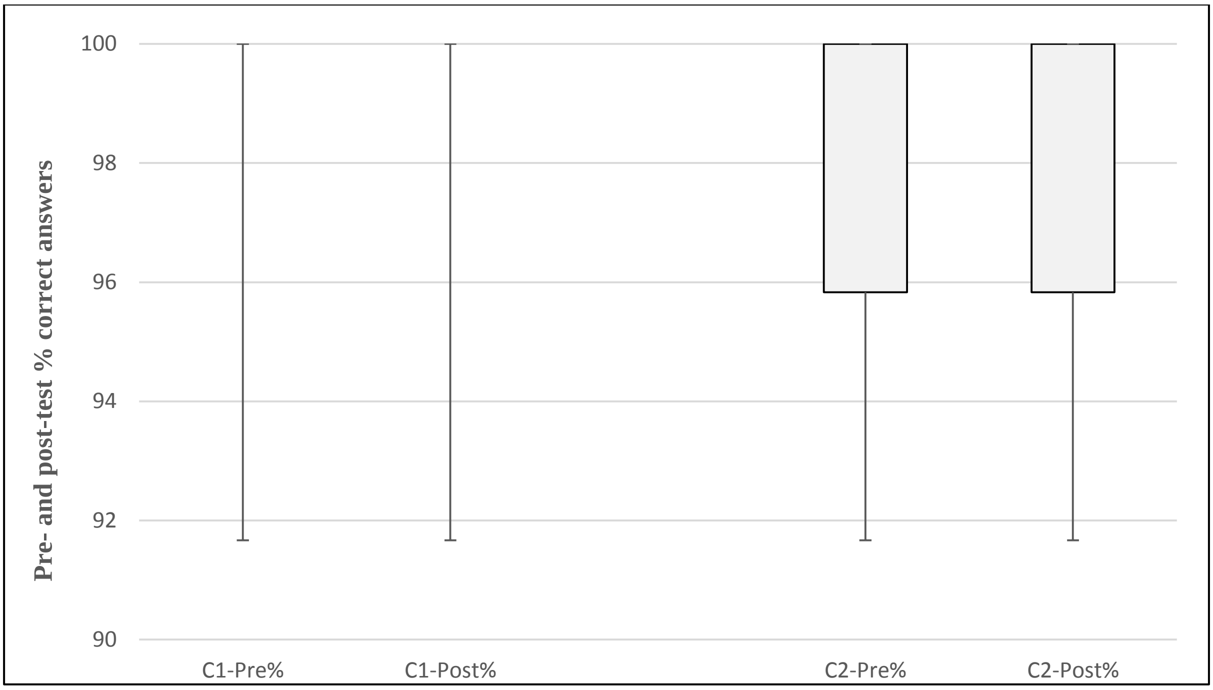


Fig. 4.14. Boxplots depicting the % correct answers for pre and post C_1 and C_2 conditions

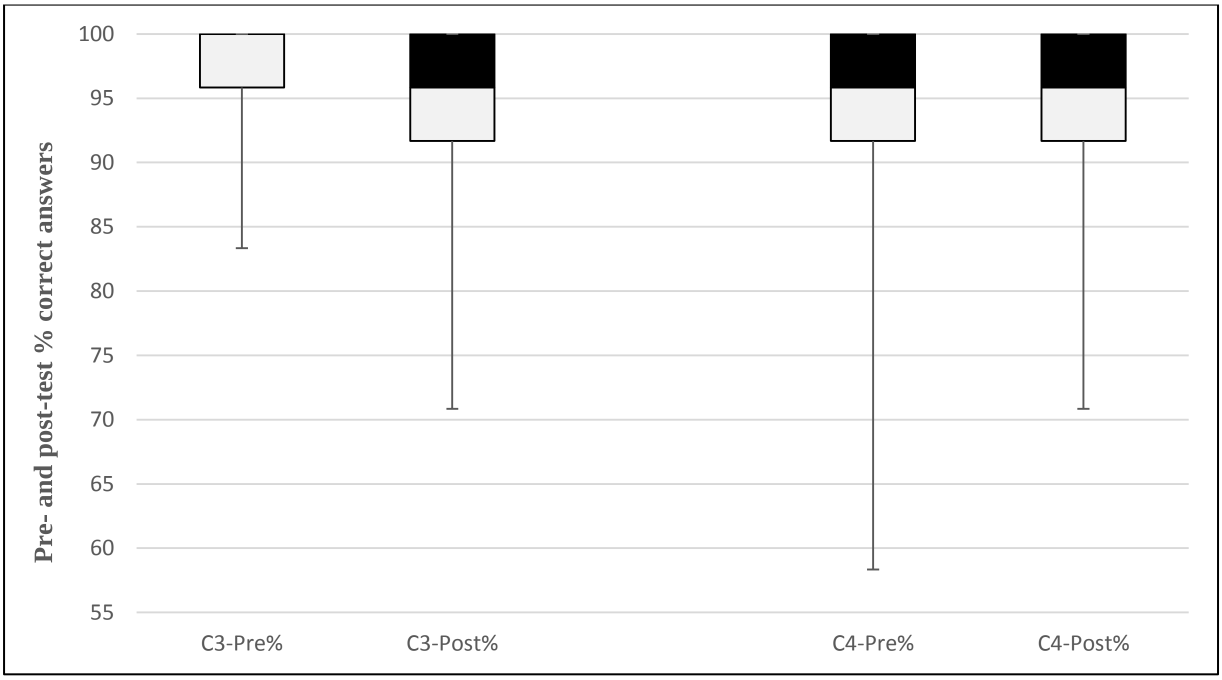


Fig. 4.15. Boxplots depicting the % correct answers for pre and post C_3 and C_4 conditions

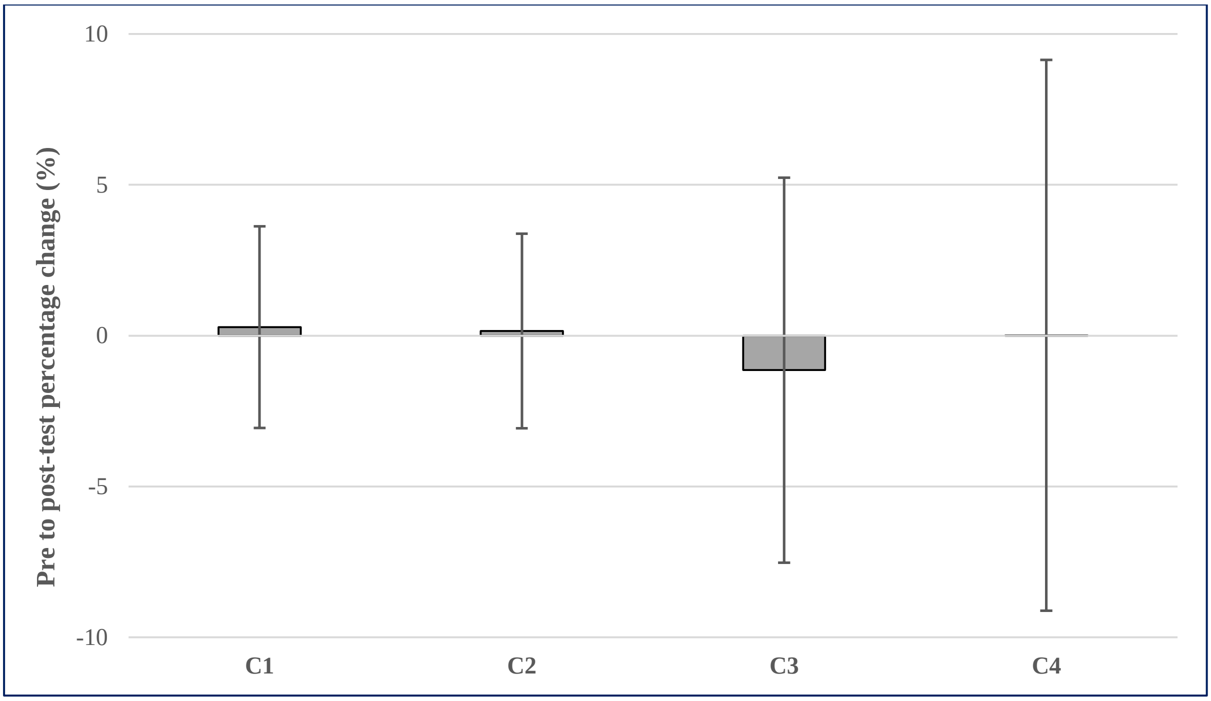


Fig. 4.16. Percentage change from pre- to post-test for correct answers on each of the four Stroop Test conditions (n = 38)

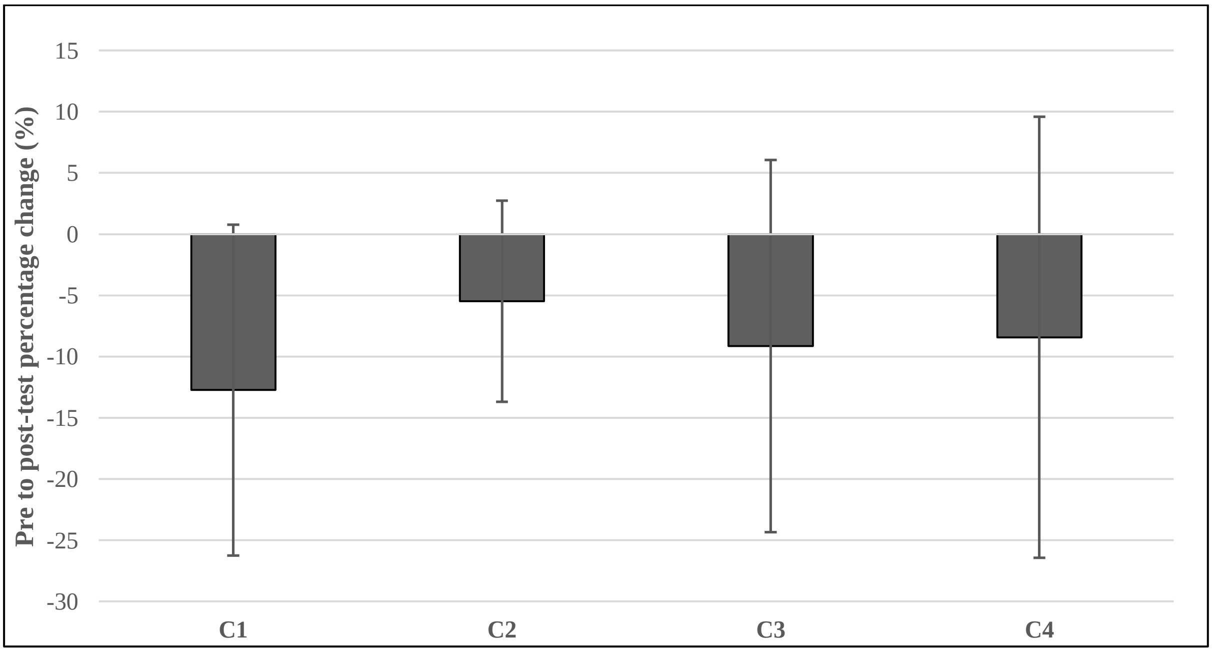


Fig. 4.17. Percentage change from pre- to post-test for the total time on each of the four Stroop Test conditions (n = 38)

Heart Rate recordings

Heart rate recordings were taken during the YYIR tests to determine the intensity level at which the referees performed the tests. The heart rate data is presented in Table 4.10. Their age predicated heart rate was calculated using the formula by Miller *et al*. (1993). The mean maximum heart rate (189.66 ± 8.61 b/min) when expressed as a percentage of their age predicted maximal heart rates was 101.26 ± 4.04 % (ranging between 93.72 % and 111.12 % of HR_{max}). This suggests that the referees put in maximum or near-maximal effort, because their maximal heart rates were on average higher than their age predicted heart rates.

Table 4.10. YYIR test results and heart rate data of the referees during the test (n = 38)

	Mean (SD)	**Range**
YYIR Level 1 (Distance to failure) (m)	962.11 ± 271.92	560.0 – 1680.0
YYIR Level 1 (indirect VO2max) (ml/kg/min)	44.48 ± 2.28	41.10 – 50.51
Age Predicted HR_{max} [a]	187.47 ± 4.35	178.70 – 197.71
Average HR (Beats/min)	160.32 ± 10.42	140.00 – 181.00
HR_{max} (Beats/min)	189.66 ± 8.61	174.00 – 211.00
% Predicted $HR_{average}$ [a]	85.60 ± 5.27	73.83 – 93.93
% Predicted HR_{max} [a]	101.26 ± 4.04	93.72 – 111.12

a Predicted HR = 217 – (0.85 x age) (according to the formula by Miller *et al*. (1993)).

Correlations between the Stroop task results and the standardised physical score

The standardised physical score were derived using the *z*-score formula shown in Chapter 3. The mean z-score of the following physical fitness performance variables results were used: vertical jump (best height), YYIR indirect VO_{2max}, 6 x 40 m RSA (best time) and CODA (best time). These variables were selected because of their importance and contribution to the running performance of the referees on the field and all four variables contributed equally to the standardised physical score.

Table 4.11 contains the correlations between the respective Stroop test results (for both the pre-test and post-test conditions) and the standardised physical performance score. It shows significant moderate negative correlations between the standardised physical score and $C_{1(pre\text{-}test)}$ and $C_{3(pre\text{-}test)}$. Moderate negative correlations are also reported between the standardised physical performance score and all four levels of the Stroop task during post-testing.

Table 4.11. Correlations between the time on each Stroop task level and the standardised Physical performance score for the total sample (n = 38)

	Spearman correlation (r)	Statistical significance (p)
Pre-test:		
C_1 - Word reading (s)	-0.40	.01**
C_2 - Colour naming (s)	-0.27	.10
C_3 - Colour and Word naming (s)	-0.34	.04*
C_4 – Mixed Colour and Word (s)	-0.11	.51
Interference (C3 – C2) (s)	-0.29	.08
Post-test:		
C_1 - Word reading (s)	-0.35	.03*
C_2 - Colour naming (s)	-0.36	.03*
C_3 - Colour and Word naming (s)	-0.32	.05*
C_4 - Mixed Colour and Word (s)	-0.35	.03*
Interference (C3 – C2) (s)	-0.09	.60

* Statistical significant correlations ($p \leq .05$) ** Statistical significant correlations ($p \leq .01$)

Table 4.12 contains the relationships between the pre- to post-test percentage change on each of the four Stroop test levels (as well as the change on the Interference score) and the standardised physical performance score. From this table it is clear that insignificant correlations exist between these variables.

Table 4.12. Correlations between the pre- to post-test percentage change on each Stroop task level and the standardised Physical performance score for the total sample (n = 38)

% Change from pre- to post-test	Spearman correlation (r)	Statistical significance (p)
C_1 - Word reading (% change)	-0.06	.74
C_2 - Colour naming (% change)	-0.24	.14
C_3 - Colour and Word naming (% change)	0.15	.36
C_4 - Mixed Colour and Word (% change)	-0.01	.96
Interference (% change)	0.20	.23

Chapter 5
Discussion

FIFA has suggested that member associations should consider age, physical condition, psychological attributes, health status, educational level and knowledge about the laws of the game when identifying and developing talented referees (FIFA, 2010). It was, therefore, important that information about elite Zimbabwean referees should be gathered and compared to studies on elite football referees from around the world in order to highlight shortcomings so that these referees could be developed to perform optimally. The study may shed light as to why fewer Zimbabwean referees are being invited for elite level competitions by determining if any of the measured variables compare poorly with the available data of other international referees.

The aim of this study was to determine the anthropometric and physical fitness profile, as well as the executive cognitive functioning (ECF) in response to exhausting exercise of elite male Zimbabwean Premier League football referees. Various anthropometric measurements were used to describe the body composition and somatotype of these referees. Their physical fitness levels were also assessed by means of the FIFA test battery, as well as a number of additional tests. The study also compared the anthropometric and physical fitness characteristics of FIFA and ZIFA referees, as well as that of referees and assistant referees. The effect of fatigue (induced by an incremental maximal aerobic capacity test) on ECF was determined, whilst the relationship between cognitive function and physical fitness was also established. The baseline data collected in this study could be helpful in the development of specific training programmes aimed at improving referees' performances.

Demographic variables

Age

Age is an important factor in refereeing as aging has been shown to cause cognitive decline and to adversely affect the physical performance of referees who may no longer be able to keep up with play during the match (Castagna *et al*., 2005a; Weston *et al*., 2010). Article 4.4 of FIFA's Statutes regarding the registration of referees and assistant referees, state that the minimum age for referees is 25 years and for assistant referees 23 years, while the maximum age is 45 years (FIFA Statutes 2013).

The mean age of the referees in the current sample was 34.89 ± 5.13 years, indicating that they were younger than the referees used in previous studies from countries such as Greece (M= 36.3 ± 4.5 years, Rontoyannis *et al*., 1998), Spain (M = 35.5 ± 4.4 years, Casajus and Castagna 2007), and Brazil (M = 37.9 ± 4.1 years, Da Silva *et al*., 2011). The FIFA referees from Zimbabwe (M = 34.20 ± 4.22 years) were shown to be younger than the FIFA referees who officiated in the 2005 (M = 39.32 ± 3.43 years) and 2013 Confederations Cup (M = 39 ± 3.5 years), respectively (FIFA, 2013). The referees in the current study were, however, older than the elite Spanish referees in the study by Caballero *et al*. (2011) who had a mean age of 26.0 ± 4.9 years. This may indicate that in Spain, referees are being recruited and trained to replace older referees at an earlier stage. The results of the current study may suggest that in Zimbabwe there is a quick rotation of referees, which could contribute to the fact that Zimbabwe referees are not visible at the highest level. The current sample was fairly young and need to be developed within a structured programme in order to gain more experience.

Education

It is a requirement that football referees should be registered under a national association so that they can be assigned to officiate in matches. Referees have to pass a test on their technical knowledge of the laws of the game as examined by the International Football Association Board (FIFA, 2010). The laws are described in English but have also been translated to German, Spanish and French. Referees need to be able to speak, read and write one of the languages so that they can understand and interpret the laws. In Zimbabwe, English is the main language, therefore, football refereeing courses are held in English and tests are also written in English.

The referees in this study met the minimum educational requirement recommended by FIFA, since all of the referees had completed Ordinary Level, which enables them to speak, read and write fluently in English. The highest educational qualification obtained by these referees was a Master’s degree, with three of the participants having completed this qualification.

Refereeing experience

Referees require experience to become FIFA licensed referees and/or to officiate in the Zimbabwean Premier League or at the international level (Caballero *et al*., 2011). The mean number of years refereeing by the elite Zimbabwean referees in this study was 10.85 ± 3.85 years, which is considerably less than that reported by Catteeuw *et al*. (2009) among Belgian referees who had 18.8 ± 4.1 years of experience, whilst the assistant referees had 15.3 ± 2.6 years' experience.

There was a significant difference between the FIFA and ZIFA referees in terms of the number of years they had been refereeing at the PSL level. The FIFA referees had a mean number of years of 6.25 ± 2.66 years officiating at PSL level compared to a mean of 3.48 ± 2.24 years of the ZIFA referees. Weston *et al*. (2009) reported that referees from England had spent an average of 5.4 years (ranging from 2 to 11 years) officiating in the top English Premier League.

The experience that the referees gained over the years is considered important by FIFA when selecting referees for elite competitions (Castagna *et al*., 2005a). Mallo *et al*. (2007) reported that elite FIFA referees who officiated in the 2005 Confederations cup had a mean number of 8.05 ± 3.39 years refereeing experience at the international level. The FIFA referees in the current sample had had their FIFA licences for a period of 3.00 ± 1.20 years. It was noticeable that the FIFA referees were assigned an average of three international matches per year. The results also showed that the FIFA referees had considerably more match assignments per month (3.38 ± 1.19) than the ZIFA referees (2.58 ± 0.79). Despite the notion that the number of years refereeing is important, game time is also central to improving the officiating skills of referees. Not only should the number of years refereeing be considered when selecting referees for elite performance, but also the number of matches they have officiated in. Therefore, the general lack of experience of the Zimbabwean referees may partially explain why they do not feature at elite competitions.

Anthropometric and Body composition variables

FIFA and the respective national federations does not prescribe any tests to determine the body composition of referees, but there is a need for consistent monitoring of body composition, because refereeing performance is affected by aging (Da Silva *et al*., 2011) and ageing results in changes in body composition. Unfortunately, there is a paucity of literature against which the body composition results of the current referees could be compared.

Stature

Lategan (2011) noted that height and body mass are usually reported in studies on referees to provide descriptive information about the sample. A significant difference between the referees and assistant referees (p = .04) was observed. The Zimbabwean referees (M = 177.85

± 7.32 cm) were taller than the assistant referees (M = 173.50 ± 5.69 cm), a trend that has previously been reported. Krustrup *et al*. (2009) reported the referees in their study to be 188 cm tall, as opposed to the assistant referees being 181 cm tall. Lategan (2011) reported similar results (referees: 173 ± 6.5 cm; assistant referees: 169.4 ± 6.7 cm), whilst the referees in Mallo *et al*.'s (2012) study had a mean stature of 182.5 ± 5.9 cm, compared to the mean stature of 178.2 ± 7.1 cm among the assistant referees. There has not been a clear explanation from the available literature as to why this trend exists. Cabarello *et al*. (2011) suggested that the taller stature of referees gives additional physical authority on the playing field and also when applying the laws of the game. Collectively, the elite referees from Zimbabwe had a mean height of 175.72 ± 6.86 cm, making them shorter than most international referees (e.g., Casajus & Castagna 2007; Mallo *et al*., 2007; Krustrup *et al*., 2009; Mallo *et al*., 2012). They were, however, taller than their South African counterparts who recorded a mean height of 171.0 ± 6.7 cm (Lategan, 2011). According to Lategan (2011), the differences in height may be the result of ethnicity and should, therefore, not be used as a measure of refereeing performance. At present though, no body composition measurements are considered when identifying, developing or appointing referees to officiate.

Body mass

Referees are required to keep up with play throughout the whole match so that they are within the optimal distance of play to make accurate decisions (Helsen and Bultynck, 2004; Weston & Helsen, 2013). To be more mobile and not to tire quickly, referees should maintain an ideal body mass. The elite Zimbabwean referees had smaller body mass values (M = 70.52 ± 10.50 kg) compared to those reported by Rontoyannis *et al*. (1998) among Greek referees (M = 81.6 ± 7.8 kg), Reilly *et al*. (2006) among English referees (M = 89.8 ± 4.8 kg), Casajus and Castagna (2007) among Spanish referees (M = 75.1 ± 6.6 kg), Mallo *et al*. (2007) among FIFA referees (M = 80.8 ± 11.1 kg), Lategan (2011) among South African referees (M = 74.08 ± 8.76 kg) and Caballero *et al*. (2011) among Spanish referees (M = 76.3 ± 13.1 kg). The low body mass values of the Zimbabwean referees may be due to their naturally small physique.

Body fat

Chamorro *et al*. (2012) pointed out that determining the levels of adiposity is important and should be considered when developing training programmes and nutritional plans for athletes (and by implication for referees). There were no significant differences between the FIFA and ZIFA referees or between the referees and assistant referees in terms of their BMI, waist-to-hip ratio (WHR), the sum of six skinfolds or the percentage body fat.

The measurements of BMI and WHR have been used widely in health surveillance programmes and to detect the risk of diseases caused by obesity (WHO, 2008). BMI has also been used as a general measure of body composition. The elite Zimbabwean referees' mean BMI value of 20.79 ± 2.47kg/m^2 fall within the normal range according to the WHO (1995), as well as the ACSM (2012) norms. These values are lower than the values reported by Reilly & Gregson (2006) among referees from England (M = 27.1 ± 5.3 kg/m^2) and Krustrup *et al*. (2009) among referees from Denmark (M = 23 kg/m^2). This indicates that the Zimbabwean referees are not fat. According to the WHO (2008), the mean WHR value of 0.83 ± 0.04 of the current sample fall within the low risk category. WHR can also help to identify the area(s) where body fat is located for example around the hips or abdominal area. There is, however, no literature on the WHR of referees against which the current results could be compared.

The sum of six skinfolds has been used to determine and reflect the amount of fat found in the adipose tissue (Casajus & Castagna, 2007; Chamorro *et al*., 2012). The mean sum of six skinfolds was 65.77 ± 24.75 mm for the current sample. In the only other study that reported the sum of six skinfolds of football referees, Casajus and Castagna (2007) found a mean of 83.2 ± 20.5 mm among Spanish referees (n = 45). The results show that the Zimbabwean referees were leaner than the Spanish referees.

The mean percentage body fat of the elite Zimbabwean referees (11.97 ± 2.60 %) calculated with Reilly *et al*.'s (2009) skinfold equation yielded lower values than the 16.7 ± 4.5 % reported by Rontoyannis *et al*. (1998) among Greek referees, the 19.3 ± 4.1 % reported by Da Silva *et al*. (2011) among national Brazilian referees and the 12.63 ± 4.2 % reported by Lategan *et al*. (2011) among South African referees.

The results of the current study show that the ZIFA referees had greater fat percentages than the FIFA referees. The results of the current study also showed lower figures in BMI, WHR, sum of six skinfolds and %BF of the Zimbabwean referees when compared with data from football referees from other countries. Body adiposity does not seem to be a limiting factor for refereeing performance, however, Da Silva *et al*. (2011) highlighted that most elite athletes have low values of body fat. It is, therefore, important that Zimbabwean referees should also maintain low body fat values as well as optimise their nutritional intake.

Somatotype

The mean somatotype of 2.68-4.62-2.65 implies that the elite Zimbabwean referees are categorised as balanced mesomorphs. This is different from the mesomorph-endomorph (3.9-4.3-1.9) classification observed among referees from Brazil (Da Silva *et al*., 2011) and the endomorphic-mesomorph (3.81-5.67-1.57) classification noted among referees from Chile (Vargas *et al*., 2008). The current results suggest that the muscular-skeletal component was dominant among the elite Zimbabwean referees, whereas Lategan (2011) found a dominancy of adiposity (4.17-3.60-2.13) among South African referees.

Correlation between age and the various body composition variables

Body composition changes over time; at first due to growth and maturation and later in life due to the effects of aging. In this study there was a strong and statistically significant linear relationship between age and WHR, BIA percentage body fat, whilst a moderate significant relationship was observed between age and BMI. These results confirm that aging influences the body composition which in turn may affect the performance of referees. It has been shown that regular exercise among aging individuals may lead to a decrease in body fat content and in turn these individuals may become muscular and carry less adipose tissue. The loss of lean body mass or muscle mass negatively affects mobility (Peterson *et al*., 2011) and thereby negatively affects athletic (and by implication refereeing) performance.

Physical fitness

Mascarenhas *et al.* (2002) stated that the correct application of football rules are related to the fitness levels of referees as they have to be close to the action at the right time, and in a good position to make correct decisions. The physical fitness results yielded significant differences regarding the one minute sit-up test and the 6 x 40 m RSA test between the FIFA and ZIFA referees. There were no other significant physical fitness differences between the FIFA and ZIFA referees or between the referees and assistant referees. These findings are most likely due to the fact that the current sample consisted of elite referees that officiated in the Zimbabwe Premier League and, therefore, follow similar training programmes. These findings are inconsistent with previous findings and expectations, as the roles and activities performed by referees and assistant referees during a match vary considerably. For example, Krustrup *et al*. (2009) reported significant differences regarding the physical demands and match activities of referees and assistant referees, whereas Weston *et al*. (2004) observed differences in the physical fitness levels of national and international referees.

One minute sit up test

The one minute sit up test was used to measure muscle endurance in the abdominal region. There was a significant difference in the sit up results of the FIFA (M = 43.63 ± 8.18) and ZIFA (36.09 ± 9.26) referees. According to the sit-up norms by Golding *et al.* (1989), the scores obtained by the FIFA referees was good, while the ZIFA referees fell in the above average category. When combined, the elite Zimbabwean referees (N = 39) on average completed 37.56 ± 9.46 sit ups in one minute, which places them in the above average category according the Golding *et al.'s* (1989) norms.

One minute push up test

The one minute push up test was used to measure upper body muscle endurance. Although the FIFA referees' performance (30.00 ± 7.73) in the push up test was significantly better than that of the rest of the participants (25.13 ± 6.42), the mean score for the total sample was 26.13 ± 6.89 push ups. Collectively the performance of these referees was classified as average according to the one minute push up norms for men aged between 30 years and 39 years outlined by Katch *et al*. (2011).

Modified sit and reach test

The modified sit and reach test was used to measure the hamstring flexibility. There were no significant differences in the modified sit and reach test between the FIFA and ZIFA referees, or between the referees and assistant referees. The mean score for the elite Zimbabwean referees was 28.31 ± 6.42 cm, which was 10 to 20 % lower than the health fitness standards reported by Hoeger and Hoeger (2005), thereby categorising their flexibility as poor.

Vertical jump test

Despite the importance of the vertical jump as a measure of explosive power only one study by Castagna *et al*. (2005a) examined the vertical jump performance of elite Italian referees. The current results of 38.63 ± 5.63 cm, compares favourably to the figures of 34 ± 3 cm for the entire group, the 36.31 ± 3.25 cm for younger referees (n = 12), the 33.00 ± 2.93 cm average aged referees (n = 14) and the 32.6 ± 3.02 cm for older referees (n = 10) reported in the afore-mentioned study on 36 Italian referees. Their study examined the age related loss of leg power in the vertical jump and showed a significant difference in the vertical jump performance of younger and older referees ($p < .03$). Among the current sample, the FIFA referees performed slightly better (41.81 ± 5.92 cm) than the ZIFA referees (37.92 ± 5.37 cm), whilst there was no difference between the referees and the assistant referees.

6 x 40 m RSA test

Several studies have reported the repeated sprint performance of football referees. The mean best time in the 6 x 40 m RSA test for the current sample was 5. 49 ± 0.22 s with the fastest recorded time of 4.91 s. This was slightly better than the mean best time of 5.59 ± 0.21 s reported by Weston *et al*. (2009) on English referees (n = 17), and the 5.70 ± 0.17 s of the 11 referees who officiated in the FIFA 2005 Confederations cup. The FIFA referees recorded significantly better times than the ZIFA referees. According to the FIFA fitness referee assistance programme training resource material (Helsen *et al*., 2013), the mean time of 5.59 ± 0.23 s recorded among the referees is rated as excellent, while the mean time of 5.65 ± 0.14 s recorded among assistant referees is rated as good.

Change of Direction Ability (CODA) test

Football referees regularly have to change direction during the match due to the nature of the game. Change of direction and agility are, therefore, important performance determinants. Castagna *et al*. (2011) classified a score of ≤ 9.67 s on the CODA as a good performance. The mean best time in the CODA for elite referees of Zimbabwe was 9.60 ± 0.42 s. This was similar to the 9.61 ± 0.45 s reported among 50 elite Italian referees by Castagna *et al*. (2011). The assistant referees were expected to perform better than the referees in this test because the test (and the running direction) is specific to the match activities of the assistant referees'. However, no such difference was observed. There was also no difference between the FIFA and ZIFA referees.

Yo Yo Intermittent Recovery (YYIR) Level One test

This specific test did not form part of the FIFA test protocol for referees. Due to the intermittent nature of refereeing activities during a match, Castagna *et al*. (2005b) suggested that the YYIR test be used to assess the aerobic capacity of referees and as a tool for identifying talented referees. The distance covered during the YYIR has been shown to be correlated with the match running capacity of football referees (Castagna *et al*., 2005b). Weston and Helsen, (2013) stated that a fitness test is only valid if it corresponds with the physical task performed, in this case being the referees' match physical activities or demands.

The results of the current study showed that there were no significant differences in the distance covered by the FIFA and ZIFA referees or between the referees and assistant referees. These referees performed poorly on the YYIR test (M = 950 ± 279 m) when compared to previous results. The lowest distance covered by a referee was 560 m (level 14.3 running at a speed of 14.5 km/h), which meant that the time to failure lasted approximately 4 minutes and 40 seconds. The maximum distance covered by a referee was 1680 m (level 17.7 running at a speed of 16 km/h), which took 13 minutes and 45 seconds to complete. Bangsbo *et al*. (2004) reported distances of 1420 ± 90 m by Danish referees, Weston *et al*. (2004) reported pre-season distances of 1720 ± 276 m among Belgium international referees, whilst the national referees in this study recorded values of 1290 ± 407 m. Castagna *et al*. (2005b) also measured a mean distance of 1503 ± 399 m among national referees from Italy.

It was expected that the referees would at least have covered similar distances to the referees from other countries. The poor results by the elite Zimbabwean referees on the YYIR test could plausibly be attributed to the fact that it was the first time that they performed this test. They were, however, familiarised before they completed the test. It could also be that the referees may have failed to recover sufficiently during the 10 seconds active recovery in between shuttles required to sustain the gradually increasing intensity levels and running-speeds of the YYIR test.

The YYIR test assesses the endurance capacity and ability of an individual to perform repeated high intensity intermittent exercise and the capacity to recover from these activities (Krustrup *et al*., 2003). The ability to continuously perform these types of activities and recover between each of the levels is deemed important for referees. The poor YYIR test results of the current sample could indicate that the referees reached their maximum effort training zones faster than other similar samples, which resulted in dropping out of the test earlier. Although all the referees in the current study managed to pass the FIFA high intensity interval test, the results show that the YYIR test identified a shortcoming in the physical fitness profiles of these participants. The future use of the YYIR test as part of FIFA's test battery for referees has some merit, as it can distinguish between referees with regard to their ability to perform repeated high intensity exercises with little recovery.

Aerobic fitness

Weston and Helsen (2013) stated that football referees should possess good levels of aerobic fitness to meet the imposed match physical demands that they face during matches. The maximal oxygen uptake (VO_{2max}) was estimated from the YYIR test using the equation by Bangsbo *et al*. (2008). This is an indirect measure of VO_{2max} and, therefore, poor performance in the YYIR level one means that similar tendencies will be observed in VO_{2max} results. The mean VO_{2max} for the elite Zimbabwean referees was 43.38 ± 2.35 ml/kg/min^{-1}. The aerobic capacity of elite Zimbabwean referees was compared to that reported in other studies that determined VO_{2max} by means of the YYIR test. For example, Krustrup and Bangsbo (2001) reported a higher mean VO_{2max} value of 46.3 ml/kg/min^{-1} (range 40.9 to 55.7) among referees from Denmark, whilst Krustrup and Bangsbo (2001) reported that a mean value of 45.9 ml/kg/min (range 40.9 to 53.6 ml/kg/min^{-1}) among Danish assistant referees. Bangsbo *et al*. (2004) reported VO_{2max} values of 47.7 ± 1.5 ml/kg/min^{-1}, 45.9 ± 1.1 ml/kg/min^{-1} and 44.7 ± 0.8 ml/kg/min^{-1} for younger, average aged and older Danish referees. Castagna *et al*. (2007) suggested a VO_{2max} of 50 ml/kg/min^{-1} as adequate for successful refereeing. The current results fall well below this value, which suggest poor aerobic fitness levels and/or an inability to maintain the high intensity levels of the YYIR test. These outcomes are mostly likely influenced by the type of training of the referees.

Executive cognitive function

Referees are required to make quality decisions and to apply the laws of the game effectively, despite the fact that fatigue gradually sets in as the match progresses. Mallo *et al*. (2012) revealed that referees tend to make more incorrect decisions during the last 15 minutes of a match for this very reason. Tomporowski and Ellis (1986) noted that individuals with higher physical fitness levels performed better in cognitive tasks than individuals with lower physical fitness levels. In a review by Lambourne and Tomporowski (2010), cognitive performance was shown to improve following submaximal aerobic exercise. Therefore, it was important to determine if the physical fitness levels of the referees had any influence on their cognitive function. To the best of the author’s knowledge no study has reported the Stroop task results among football referees.

There was a significant improvement in the time taken to complete the easy conditions (C_1 and $C_{2)}$, whilst a moderately significant improvement was reported for the more difficult condition (C_3) and a small significant improvement in the most difficult condition ($C_{4,}$). The results showed that there were significant improvements in the time, but not in the correctness of answers (probably due to the range restriction of this aspect of the test; a high percentage of correct answers were recorded). There was a moderate practical significant difference between the pre- and post-test interference scores. These results are similar to those found by Chang and Etnier (2009), Yanagisawa *et al*. (2010), Alves *et al*. (2012), as well as Rattray and Smee (2012). These studies also reported that improvements in the time to completion did not affect or compromise the accuracy of answers in the Stroop task. The results from the current study also support the conclusion by Tomporowski (2003) that exercise improves response speed.

The referee's performance on the Stroop task improved significantly from pre- to post-test. The YYIR level one test is an incremental test and the results show that a number of the referees pulled out during the early stages of the test, despite their heart rate data showed that they performed the test at a mean of 101.26 ± 4.04 % of their age predicted maximal heart rate. They may have pulled out, because of the rapid increase in the running speed of each progressive level of the test, indicating that this test may have been too tough for them. The participants were allowed to stop when they could no longer continue the test; therefore, the YYIR test probably only induced acute fatigue and was not sufficient to illicit a decline in cognitive functioning normally expected with refereeing a 90-minute match. The duration of the test might have been insufficient to negatively affect ECF, since the time before dropping out of the test ranged from 4 minutes and 40 seconds to 13 minutes and 45 seconds. The high level of exertion over the relatively short duration of the test, therefore, seem to have facilitated an improvement in cognitive function, as the intensity level and/or duration were insufficient to have an adverse effect on the cognitive functioning. The improvement in the cognitive functioning is consistent with past literature that showed that acute exercise bouts had positive benefits on cognitive function (Brisswalter *et al*., 2002; Tomporowski, 2003). Tomporowski (2003) observed that increased physical activity for a duration of up to 60 minutes lead to a significant increase in cognitive function. He concluded that acute bouts of exercise have various cognitive function benefits that include improvements in problem-solving, response accuracy, response speed and inhibition. It is plausible that the YYIR level one test may have improved the transportation of energy and oxygen to the frontal lobes that contributed to an improvement in the ECF.

According to McMorris (2008), an increase in exercise intensity may lead to changes in arousal levels and in turn benefit cognitive processes. Chang and Etnier (2009) pointed out that there is an inverted-U relationship between physiological arousal and cognitive performance. The improved pre- to post-test cognitive function results may also have demonstrated that the referees had become conditioned to perform optimally even if they were fatigued. Sibley *et al*. (2007) attributed the ability of an individual to overcome interference to the process of goal-orientation and attention.

There was a positive correlation between the number of correct answers and time to complete the Stroop test for C_3 (pre-test) and C_1 (post-test), which implies that taking longer to complete each test improved the accuracy of the answers. However, football referees often need to make quick, but accurate decisions. They need to apply the laws of the game before making correct decisions for each match situation and as such decisions made during the match are not automatic; they require effort and cognitive functioning. Chodzko-Zajko and Moore (1994) stated that cognitive functioning tasks need allocation of attentional resources to be successfully completed.

Although the magnitude of the correlations found between the physical fitness (standardised physical fitness) results and the Stroop task results was only moderate, it does indicate that physical fitness and cognitive functioning is significantly correlated. It is essential to find ways to maintain and enhance the cognitive functioning of referees due to the nature of their work. Their performance depends on their ability to simultaneously keep up with play while making accurate and crucial decisions during the match. Emphasis has been placed on the importance of referee's possessing high levels of fitness because of its effects on cognitive functioning and decision making ability (Helsen & Bultynck, 2004; MacMahon *et al*., 2007; Mallo *et al*., 2012). The observed improvements in the cognitive task performance may, therefore, relate to the referees' ability to maintain high levels of cognitive functioning even when they are affected by fatigue.

Even though the YYIR is not part of the FIFA fitness test battery, the test is deemed relevant, since it contains repeated, intermittent movements at intensity levels similar to those experienced by referees during matches. The YYIR test was used to induce fatigue before administering the Stroop task that was used to assess cognitive functioning of referees. However, the fatigue induced by the YYIR test did not negatively affect the cognitive functioning of the referees. These results, may mean that referees have become conditioned to sustaining match related physical demands and at the same time maintain their ability to make decisions during the match.

Chapter 6
Summary, Limitations and Recommendations

Summary

No previous study could be found that profiled elite male Zimbabwean football referees. The study revealed that the referees were not obese and, therefore, not at risk of cardiovascular diseases. The results also showed that the elite male Zimbabwean referees were shorter and weighed less than referees who participated in other studies. The referees were found to be taller than the assistant referees. The somatotype results revealed that the majority of the referees in the current study were balanced mesomorphs. This indicates that the elite male Zimbabwe referees tend to be quite muscular.

The referees in this study had acceptable physical fitness levels to officiate in the Premier League, however, they had considerably lower aerobic capacity (VO_{2max} scores) than those reported in previous studies. The lower aerobic capacity may negatively affect their performance, in trying to keep up with play and sustaining the physical demands of the match. It is important that referees incorporate training that improves their maximal aerobic power and endurance using intermittent and high intensity training programmes. The physical exertion during the YYIR level one test improved the cognitive functioning of the referees. There was also a small, but statistically significant relationship between cognitive functioning and physical fitness.

This study lays a foundation for future studies about the anthropometric, physical fitness and cognitive characteristics of elite Zimbabwean referees. The results from the present study will allow those working with referees to compile specific training programmes to improve their physical fitness and to monitor their body composition. Furthermore, the results from this study can be utilised to develop criteria for identifying and developing talented young referees in Zimbabwe. In doing so their chances of being selected for elite competitions locally and internationally may improve.

Limitations

The current study had several limitations which need to be addressed to improve future studies.

- To the researcher's knowledge, this was the first study to be conducted among football referees in Zimbabwe. The results of this study cannot be generalised to represent all the referees in Zimbabwe due to the fact that the study only focussed on referees that were officiating in the Premier League of Zimbabwe. Furthermore, the sample size of the FIFA referees was small hence the results have limited generalizability.

- During the second phase of the data collection, the referees had to be visited in towns/areas where they lived. This meant that referees were exposed to different weather or environmental conditions although all of the testing occurred in favourable weather conditions. The difference in weather conditions from one town to the other and the time during the day the tests were conducted could also have affected the performance of the referees. Different running surfaces were used, but the researcher searched and used the best and similar running surface available in each area. For future studies it is important that the referees are tested under exact similar conditions.
- During the second phase of the study, the referees performed the tests individually. Therefore, the participants may have lacked support and competition and as a result they may have failed to put maximum effort during the CODA and YYIR tests. Social facilitation due to others performing the test at the same time has been shown to enhance effort and performance.
- The referees had little time to familiarise themselves with the CODA and YYIR tests which were introduced to them during the first phase of the study. The lack of familiarisation might have had a negative impact on their performance. It could have been helpful to set a minimum number of practise sessions that one had to complete before they could participate in the study to reduce the level of uncertainty and possible anxiety during the test.
- The YYIR level one results was used to estimate the maximal oxygen uptake. This is an indirect measure of VO_{2max} and, therefore, poor performance in the YYIR level one test means that similar tendencies will be observed in VO_{2max} results.
- It was not possible to calculate the actual mean heart rates of the referees during the YYIR due to the fact that the heart rate monitor recordings included the instructional phase of the YYIR audio clip. This included the recordings from the start of the audio clip roughly 10 seconds before the start of the test, instead of starting the recording at the beginning of the running phase. Therefore, it is important that the heart rate reading should be recorded from the start of the running phase or by using heart rate monitors with software that allows the deletion of unwanted data.

- Despite the fact that the cognitive test results showed some improvements after the YYIR test, the Stroop task may not necessarily be the most relevant test for football referees. The Stroop task remains one of the most frequently used, valid and reliable tests to measure executive cognitive functioning. However, the nature of refereeing and the stressful environment in which referees fulfil their duties probably requires tests that simulate real match situations (in terms of the type, intensity and duration of physical activity, as well as having to make decisions similar to ones encountered during matches). Vigilance and tracking tests might, therefore, be more appropriate for referees.
- In order to increase the generalizability of the Stroop task results, it is important to use a larger sample size and also to include referees from a wider age range as age may have an effect on the results.
- Although the use of the YYIR test revealed shortcomings with regard to the ability of the participants to repeatedly perform high intensity intermittent sprints, the duration of the test was insufficient to illicit fatigue and a decline in cognitive functioning.

Recommendations and future research

- There is a need for constant, measuring and continuous monitoring of the referee's body composition. Longitudinal studies are, therefore, required.
- Since age has been found to have an influence on several body composition and physical fitness variables, there is need to recruit young talented referees with appropriate aerobic and anaerobic capacity. Such a move will afford young referees to gain exposure and experience at an early age.
- Despite the fact that the YYIR is not a FIFA recognised fitness test, it should be considered for future testing of referees. The minimum distance the referees should be able to complete should also be determined for each of the different refereeing categories.
- Referee fitness instructors should consider using a variety of relevant fitness tests and not only the tests recommended by FIFA, as the game of football is changing fast. The current study also showed that whilst the referees performed well in most of the tests, they performed poorly in the YYIR test, which highlights a need for improvement with regard to their ability to perform repeated high intensity runs.
- Future studies should determine the effects of a specific high-intensity training programme on the referees' physical fitness levels. In this regard Weston *et al.* (2004) argued the need to evaluate the effects of prescribed training programmes.

- Since this was the first study among referees to use the Stroop Task, future studies should consider using other cognitive tests that may be more relevant to the actual demands of officiating matches.
- Future studies should also use a protocol which simulates the actual activities (duration and intensity) as well as the decision-making challenges facing referees during matches.

Recommendations for applied practice

- There are many important factors for a successful career as an elite football referee. These include optimal morphological characteristics, being physically fit and able to make correct decisions during the match. It is important that referees are constantly educated about these aspects and its role in a successful career.
- The FIFA protocol for the testing of referees does not include any body composition measurements, apart from BMI which forms part of the medical screening. It is important that FIFA considers using body composition measurements to monitor referees as well as to compliment and optimise their health and performance.
- Referees and assistant referees should engage more regularly in role specific training programmes that are aimed at maintaining high and appropriate physical fitness levels to prepare them for the specific match demands. For example, training programmes for assistant referees should include changing of direction and sideways running.
- Physical fitness tests are an important benchmark and should be performed regularly as part of an integrated system aimed at developing referees and making sure that they are ready to officiate at the highest level. It is also important that FIFA uses physical fitness tests that are able to discriminate between successful and less successful referees. Tests such as the YYIR test shows promise to be included. Alternatively, this test could be adapted to simulate the specific activity demands placed on referees during matches.
- The current sample of referees has to improve their aerobic capacity and/or their ability to sustain repeated high intensity running bouts. Heart rate recordings during training sessions should provide feedback about the time spent in various training zones, which could be valuable to the trainers to individualize training programmes instead of prescribing a generic programme for all the referees.
- The referees should also be subjected to more cognitive or decision making activities in their training programmes to improve their concentration ability, their ability to supress and/or ignore irrelevant stimuli and activities that improve visual skills to help them make good and correct decisions in the shortest possible time.

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Appendix One – Ethics Approval Letter

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Approved with Stipulations

New Application

20-Jun-2013
Banda, Morris M

Proposal #: DESC_Banda2013

Title: ANTHROPOMETRIC PROFILE, PHYSICAL FITNESS AND COGNITIVE FUNCTIONING OF ELITE ZIMBABWEAN FOOTBALL REFEREES

Dear Mr Morris Banda,

Your **New Application** received on **14-Jun-2013**, was reviewed by members of the **Research Ethics Committee: Human Research (Humanities)** via Expedited review procedures on **27-Jun-2013**.

Please note the following information about your approved research proposal:

Proposal Approval Period: **18-Jun-2013 -17-Jun-2014**

The following stipulations are relevant to the approval of your project and must be adhered to:
Informed consent: Language needs editing.
REC Application: Section 9.3 When results be made available be aware that no participant can be indentied

Please provide a letter of response to all the points raised IN ADDITION to HIGHLIGHTING or using the TRACK CHANGES function to indicate ALL the corrections/amendments of ALL DOCUMENTS clearly in order to allow rapid scrutiny and appraisal.

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**DESC_Banda2013**) on any documents or correspondence with the REC concerning your research proposal.

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

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 0218839027.

Sincerely,

Susara Oberholzer
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

Appendix Two – Letter of Permission to carry out the study from the Zimbabwe Football Association Referees Committee

ZIMBABWE FOOTBALL ASSOCIATION

REFEREES COMMITTEE

P.O. Box Cy114
Causeway
Harare, Zimbabwe
53 Livingstone Ave.
Tel: +263 -4-798628/31
721028
Tel/fax: +263-4-798626
E-mail: zifa@africaonline.co.zw
zifarefereescommittee@gmail.com

16 May 2013

Dear Mr Banda,

Ref: PERMISSION TO CARRY OUT A STUDY AMONG ZIMBABWEAN FOOTBALL REFEREES

We would like to thank you for your letter dated 14 May 2013 requesting for permission to carry out a study among football referees. It has been a pleasure working with you over the few years in the physical fitness department of the Referees Committee.

We are pleased to inform you that the Zimbabwe Football Association Referees Committee has granted you permission to carry out a study titled "Anthropometric profile, physical fitness and cognitive functioning of elite Zimbabwean football referees".

The Committee agreed that you can collect your data among football referees during the FIFA Member Association course to be held from 14 to 18 August 2013 and that you can use the results obtained from the study in your Masters Degree thesis and academic research journal publications.

We believe that such studies will positively contribute to the overall improvement of referee's performance in Zimbabwe.

We wish you well in your studies.

Yours faithfully

Tendayi Bwanya
ZIFA Referees Committee
SECRETARY GENERAL

MEMBER OF

FIFA

Appendix Three – Informed Consent Form

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STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

Anthropometric Profile, Physical Fitness and Cognitive Functioning of Elite Zimbabwean Football Referees

You are asked to participate in a research study conducted by **MORRIS BANDA** (B.Sc. Hons. Sports Science and Coaching) from the Department of Sport Science at Stellenbosch University. You were selected as a possible participant in this study because you are:

I. Officiating in the 2013 Zimbabwe Football Association Premier League.
II. A registered male 2013 Fe´de´ration Internationale de Football Association (FIFA) International referee
III. A registered male 2013 Zimbabwe Football Association Premier League.

1. PURPOSE OF THE STUDY

The purpose of the study is to profile the anthropometric, physical and cognitive functioning of elite Zimbabwean football referees.

2. PROCEDURES

If you volunteer to participate in this study, we will do the following/ ask you to do the following:

2.1. Demographic data - You will be requested to provide information about yourself and your refereeing career.
2.2. We will measure your resting blood pressure.
2.3. You should wear minimum clothing (for example t-shirt and a short) for anthropometric measurements. The following anthropometric variables will be measured according to the standard procedures described by the International Society for the Advancement of Kinanthropometry (Norton & Olds, 1996):
   1. Height
   2. Body mass
   3. Eight (8) skinfolds (biceps, triceps, subscapular, iliac crest, supraspinal, abdominal, front thigh, and medial calf) using a skin fold callipers
   4. Five (5) girths or circumferences (arm relaxed, arm flexed and tensed, waist, gluteal and calf) using an anthropometric tape
   5. Two bone (2) breadths (humerus and femur) using a sliding callipers.
2.4. We will measure body fat and fat free mass using the Bioelectric Impedance Analyser. You will be asked to lie facing up (in the supine position) and two electrodes will be attached or connected to your right arm and leg to allow us to take the readings.
2.5. You will be asked to complete the following physical performance tests:
   1. Sit and reach (Flexibility)
   2. Vertical jump (Leg power)
   3. Sit up and push-up (Strength and muscular endurance)
   4. 6 x 40m sprints (Speed)
   5. 10-8-8-10m change of direction ability (Agility)
   6. Yo Yo intermittent recovery level 1 (Aerobic endurance)
2.6. You will be asked to wear a heart rate monitor to measure heart rate during the Yo-Yo intermittent recovery level 1.
2.7. You will be asked to take the Stroop task to assess cognitive function before and immediately after the Yo-Yo intermittent recovery level 1.

3. POTENTIAL RISKS AND DISCOMFORTS

The exercise intensity during the vertical jump test, agility test and 40m repeated sprint ability will be similar to what you will experience during your training and when you are officiating in a football game. The Yo-Yo intermittent recovery level one may be uncomfortable and tiring as you will be asked to give your best or maximum effort. You may have muscle soreness the next day. However, the exercise intensity should be similar to the intermittent movement you would experience during a match. All testing sessions will be supervised by a medical doctor or state registered nurse.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

For participating in the study, you will be able to get information on your current physical, body composition and cognitive functioning status. You we receive feedback that is important to help you improve and maximise on your performance as a referee. Your participation in the study will contribute to the creation of a data base for referees profile in Zimbabwe. The data that will be collected will help in understanding the current anthropometric, physical, and cognitive functioning status of Zimbabwean referees. This will help in designing training programmes that are relevant and suitable to Zimbabwean referees in an effort to raise the level of match fitness.

5. PAYMENT FOR PARTICIPATION

You will not be charged any amount for participating in the study. However during the second part of the study participants will be provided with refreshments on the day of testing.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of put password protection on data stored on computers and locking up all the collected data in the study leader's office at the Department of Sport Science for safekeeping. Information relating to the study will only be accessible to the research team. Participants of the study will not be identified by their names, as a code number will be allocated to each participant. The documents with specific code numbers linking the participants' identities will be kept separate from the rest of the records. Participants will be given an individual report after the tests. The group results of the study will be published in a scientific journal or presented at scientific conferences and confidentiality of participant's names will be maintained. The data collected will be kept for a period of five years.

7. PARTICIPATION AND WITHDRAWAL

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 consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so. In a case where you are ill, injured or if there are any adverse effects.

8. IDENTIFICATION OF INVESTIGATORS

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

Mr. Morris Banda (Principal Investigator), Cell: +263 772 896 138, Email: 17030358@sun.ac.za or morrisbanda23@gmail.com.

Dr. H.W. Grobbelaar (Supervisor), Telephone: +27 21 808 4771, Email: hgrobbelaar@sun.ac.za

Prof. E. Terblanche (Co-Supervisor), Telephone: +27 21 808 4817, E-mail: et2@sun.ac.za.

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, 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 ________________________________ by Morris Banda in English/Ndebele/Shona and I am in command of this language. I was given the opportunity to ask questions and these questions were answered to my satisfaction.

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

____

Name of Subject/Participant

____

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 ________________________ and he was encouraged and given ample time to ask me any questions. This conversation was conducted in English/Ndebele/Shona and no translator was used.

______________________ ______________

Signature of Investigator **Date**

Appendix Four: Data Sheet

University of Stellenbosch
Department of Sport Science

Name: ____________________ **Code:** ____________________

Date of Birth: ____________________ **Male/Female:** ____________________

Date of Testing: ____________________ **Referee/Assistant:** ____________________

Weight: ____________________ **Height:** ____________________

Body Composition

Data to collect	Values	Normative ranges
% Body Fat		
% Lean Body Mass		
Predicted Weight		
Resting Energy Consumption	Kcal	KJ
Energy Required	Kcal	KJ
H_2O Content		
Body Mass Index		
Body Fat Mass Index		
Fat Free Mass Index		

Physical Fitness Test

	1	2	3
Change of Direction Ability			
Modified Sit and Reach Test			
Vertical Jump Test			
1minute Sit up Test			
1minute Push-up Test			

	1	2	3	4	5	6	7
40m Sprint Test							
Yo Yo Intermittent Level One							

Appendix Five: Refereeing History

Refereeing History

Code: ______________________________ **Match Referee** ☐ **Assistant** ☐

Education

Please indicate the highest level of education. **Primary/High school:** ☐

'O' level: ☐ **Technical/College Diploma:** ☐ **Certificate:** ☐

Degree: ☐ **Masters:** ☐ **PhD:** ☐

Profession: __________________________________

1	When did you receive the first official license for refereeing?		
2	When did you receive the FIFA license for refereeing?		
3	When did you start refereeing for the Premier League?		
4	When did you start officiating international matches?		
5	How many national matches do you officiate per year?		
6	How many international matches have you officiated?	**Competition**	**No. Of Matches**
7	On average, how many national and international matches do you officiate per year?		
8	What is the maximum number of matches per month have you officiated in the past twelve months?		
9	Did you incur an injury in the last six months?	**Yes**	**No**
	Please specify the injury.		
	Is it mild or severe?	**Mild**	**Severe**
10	Are you on any medication?	**Yes**	**No**
	If so what medication are you taking?		

Appendix Six – Anthropometric Data Sheet

Stellenbosch University

Department of Sport Science

Test ID: ________________________ Lab Tester ID: ________________________

Name: ________________________ D. O. B.: ________________________

Test Date: ________________________ Gender: M ☐ F ☐

Body Mass: ________________________ Height: ________________________

	SITE	TRIAL 1	TRIAL 2	TRIAL 3	MEDIAN
Skinfolds (mm)	Triceps				
	Subscapular				
	Biceps				
	Iliac crest				
	Supraspinale				
	Abdominal				
	Front thigh				
	Medial calf				
Girths (cm)	Arm relaxed				
	Arm flexed and tensed				
	Waist				
	Gluteal (hip)				
	Calf				
Breadths (cm)	Humerus				
	Femur				