Endocrine Response to Small-Sided Games and Match Play in Elite u19 South African Soccer Players

By
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Declaration

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Summary

Purpose Small-sided games (SSGs) are used worldwide with the intention of stimulating significant physiological adaptations in players that are specific to match demands. The external load of SSGs and matches in soccer is well documented, but far fewer studies are aimed at measuring the internal response to these activities. The endocrine response to SSGs and matches in soccer is less well known although the respective hormones; cortisol, testosterone and dehydroepiandrosterone (DHEA) provide a valid measure of training load and total stress in several other methods of exercise. This study aimed to measure the internal endocrine response to training and matches and identify any variations between playing position and whether SSGs were preparing the players for match demands.

Methods 22 elite male soccer players (16 – 23 years old), divided into positional subcategories of goalkeeper (n = 4), defender (n = 7), midfielder (n = 5), and attacker (n = 6) provided saliva samples; at rest, in response to 11v11, 7v7, and 4v4 SSGs, friendly and competitive matches, and a yoyo level two intermittent endurance test (YoyoII). Cortisol, testosterone, T:C, and DHEA concentrations were analysed using an ultra-high-performance liquid chromatographic method with mass spectrometric detection in response to small-sided games and matches. Statistically, hormones were analysed through one and two way ANOVA's to compare different time points and positions.

Results Cortisol (ng/ml) increased significantly (0,70 ± 0,40 SD to 3,94 ± 3,26 SD) from resting values in response to competitive match-play immediately after the match amongst the squad as a whole ($p < 0.01$). Cortisol increased significantly during all small-sided games ($p < 0.05$). T:C ratio (ng/ml) significantly decreased (0,89 ± 1,93 to 0,19 ± 0,28) from resting values in response to competitive match-play ($p < 0.01$) while testosterone showed no significant changes in response to match-play. No significant differences were found between the endocrine response of all positional subgroups over any SSGs or matches. DHEA presented no significant changes between all time-points and T:C ratio remained constant throughout the eight month testing period. SSGs presented no significant differences in endocrine response based on the number of players on the field. Yoyo2 produced comparable endocrine response to those at rest amongst the squad as a whole.

Conclusions SSGs do not prepare soccer players for matches because they do not stimulate the same stress response than matches. The stress response is likely correlated to more than just physical exertion, therefore cortisol could be used as an indicator of total stress including anxiety and emotional stress as opposed to physical stress alone. Different positions do not result in different internal responses to training and matches regardless of differing external positional requirements. SSGs as a method of training seems to present no risk of overtraining. Future studies should seek to correlate cortisol, testosterone and DHEA with other, more affordable measures of internal training load or be used in conjunction with external training load measures. Future studies should perform repeated testing on smaller study samples due to the high intra-individual variability of endocrine response between time-points.

Keywords: Small-sided games; T:C ratio; match-play; soccer

Opsomming

Doel Klein-groep spele word algemeen in die wêreld gebruik met die doel om betekenisvolle fisiologiese aanpassings, wat spesifiek tot die vereistes van wedstryde is, by spelers te veroorsaak. Die eksterne lading van klein-groep spele en wedstryde in sokker is goed gedokumenteer, maar baie minder studies poog om die interne response op hierdie aktiwiteite te meet. Endokriene response op klien-groep spele en wedstryde in sokker is nog meer onbekend en tog is dit bekend dat die hormone kortisol, testosteroon en dehidorepiandrosteroon „n geldige meting vir oefenlading en totale stres van verskeie ander oefenmetodes is. Hierdie studie is uitgevoer om die interne, endokriene response op oefening en wedstryde te meet, te bepaal of hierdie ladings tussen speelposisies verskil, en of klien-groep spele die spelers voldoende voorberei vir die eise van wedstryde.

Metodes 22 elite sokkerspelers (16 – 23 jaar oud), verdeel in subkategorieë volgens posisies as doelwagter (n = 4), verdediger (n = 7), middelbaanspeler (n = 5), en aanvaller (n = 5), het speekselmonsters tydens rus, in reaksie op 11v11, 7v7, en 4v4 klein-groep spele, „n vriendskaplike en kompeterende wedstryd, asook „n yoyo vlak twee uithouvermoë toets, verskaf. Kortisol-, testosteroon-, testosteroon-kortisol-ratio (T:C), en dehidorepiandrosteroon-konsentrasies (DHEA) is analiseer volgens „n ultra-hoëprestasie vloeistof chromatografiese metode met massaspektrometriese vassteling vir reaksie op klein-groep spele en wedstryde. Statistiese analises is gedoen volgens een- en twee-rigting ANOVAS om die hormone op verskillende tydpunte en tussen verskillende posisies te vergelyk.

Resultate Kortisol (ng/ml) het statisties beduidend toegeneem (0,701 ± 0,401 tot 3,938 ± 3,259) vanaf rustende waardes in reaksie op kompeterende wedstryde direk na die wedstryd binne die groep as geheel ($p < 0.01$). Kortisol het ook statisties beduidend toegeneem in reaksie op al die klein-groep spele ($p < 0.05$). T:C ratio (ng/ml) het beduidend verlaag (0,891

± 1,929 tot 0,193 ± 0,2800) vanaf die rustende waardes in reaksie op die kompeterende wedstryd ($p < 0.01$), terwyl testosteroon geen beduidende verandering getoon het in reaksie op die wedstryd nie. Geen beduidende verskille is gevind in die endokrienresponse by die verskillende posisies vir al die klein-groep spele of wedstryde nie. DHEA het geen beduidende veranderinge getoon by enige van die tydpunte nie en die T:C ratio het relatief konstant gebly oor die toetsperiode van agt maande. Klein-groep spele, gebaseer op die aantal spelers op die veld, het geen beduidende veranderinge in endokrienresponse meegebring nie. Die Yoyo2 het endokrienresponse meegebring wat vergelykbaar is met die metings van die hele groep tydens rus.

Gevolgtrekking Klein-groep spele is moontlik nie die beste manier om sokkerspelers vir wedstryde voor te berei nie, aangesien dit nie dieselfde stresresponse veroorsaak as wedstryde nie. Stresresponse is waarskynlik verwant aan meer as net fisieke inspanning en kortisol kan gebruik word as aanduiding van totale stres, wat angs en emosionele stress insluit, in teenstelling met net fisieke stress. Verskillende speelposisies lei nie noodwendig tot verskillende interne response op oefening en wedstryde nie, ten spyte van die verskillende posisionele eise. Klein-groep spele as oefenmetode hou waarskynlik nie „n risiko vir ooroefening in nie. Toekomstige studies kan kortisol, testosteroon en DHEA met ander meer bekostigbare metodes vir die meet van interne lading vergelyk, of kan gebruik word saam met metings van eksterne ladings. Bykomend, kan toekomstige studies „n kleiner groep deelnemers gebruik, maar meer herhaaldelike metings doen as gevolg van die hoë intra-individuele variasie in endokrienresponse by verskeie tydpunte.

Sleutelwoorde: Klein-groep spele; endokrienrespons; wedstryde; sokker, kortisol, testosteroon

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List of Abbreviations

11v11	– Eleven players versus eleven training game
7v7	– Seven players versus seven training game
4v4	– Four players versus four training game
CT	– Cape Town
DHEA	– dehydroepiandrosterone
FCTR	– free testosterone/ cortisol
ratio FA	– Football Association
FC	– Football Club
FIFA	– Fédération Internationale de Football Association
HR	– Heart rate
RPE	– Rating of Perceived Exertion
sRPE	– session Rating of Perceived
Exertion SSG	– Small-sided game
SSGs	– Small-sided games
YoyoII	– Yo-Yo intermittent endurance test level 2
U19	– under nineteen years old
UEFA	– The Union of European Football Association

Chapter One

Introduction

Overview of literature

> "The sphere is as old as the world. Kicking is as old as humanity.
> The Ancients knew the ball, but football is born of modernity"
> (Goldblatt, 2006, p. 18).

Before discussing and analysing the modern game that is association football (soccer), and any specifically related training principles used in the 21st century (such as small-sided games), it is important to understand the history of soccer. Without knowing the history of soccer and the gradual, yet meteoric rise to the state that the sport finds itself in today, there is no use in trying to understand the necessity of such specific training principles. For what was once a mere game with humble beginnings, is now the most popular sport in the world with over 265 million participants worldwide at the time of the last FIFA Big Count in 2006 (Kunz, 2007). The unrelenting modernization of the sport has necessitated improved training methods, increased professionalization and has resulted in soccer being the majority contributor in a global sports industry valued at $480 - $620 billion in 2011 by A.T. Kearney (Collignon, Sultan, & Santander, 2011). Now more than ever, the words of the late Bill Shankly ring true, "Some people think football is a matter of life and death. I assure you, it's much more serious than that".

Sports writer David Goldblatt wrote a book which was published in 2006 titled, *The Ball is Round: A Global History of Football*, which attempts to explain the history of soccer through the thorough examination of all existing texts that lead it to the sport it is today. The remainder of this chapter will attempt to provide the reader with an analysis of that progression before the in-depth analysis of training principles and methods in the chapters to follow. Additionally, a special focus will be made on Dutch football and the football of Ajax Amsterdam FC as this study took place at Ajax Cape Town FC, the daughter club of Ajax Amsterdam.

Soccer is a game so ancient, there is still a debate today as to where it originated. The ancient Chinese sport "*cuju"* translated into "kick-ball" dates as far back as 206 BCE, while Japanese nationalist historians insist that medieval "*kemari*" dates as far back as the sixth century BCE (Goldblatt, 2006). Aboriginal Australians had their own soccer-like pastime known as "*Marn Gook"* described by white Australians in the 1840s as:

> "a kynd of exercise that have often amongst them much like that which boyes call bandy in English and may be aunceynt game. They have the exercise of Footeball, in which yet they only forceibly encounter with the foote to carry the Balle the one from the other, and spurne it to the goale with a kind of dexterity and swift footmanshippe, which is the honour of it" (Goldblatt, 2006, p. 8)

Goldblatt (2006) suggested that in an alternative history, where China, Japan and Australasia had industrialised either before or alongside Europe, a sizeable portion of the world would be playing an alternative to modern day soccer. Goldblatt (2006) suggested that it is of little importance as to where soccer originated but rather who played the game at the moment of modernization.

Goldblatt (2006) attributes the origins of modern football (soccer) to the Celtic cultures and societies of the Western Fringe. He suggested that while the ancient European societies of Rome and Greece did not play many ball-related games, the Celtic and Western Fringe societies managed to elude the control of Rome even at the height of its powers and thus maintained their traditional roots and practices. Goldblatt (2006) states that on the western edge of the European peninsula, Celtic-speaking cultures managed to remain relatively autonomous throughout the medieval era. During this time, all of these nations appeared to have played large-scale, kicking-based, ball games. While these games, much like the games from ancient times were threatened in-terms of their longevity, soccer became an indelible feature of the lower orders. In the eighteenth century, a sporting culture was emerging in western Europe and soccer was one of those many sports. Thus, Goldblatt (2006) attributed the origin of soccer to the chance encounters of immense historical forces in Anglo-Celtic melees in the eighteenth century and those who survived them.

Soccer continued to survive and later thrive in Britain thanks to its popularity amongst school children. In the mid nineteenth century, the games ethic had become a central ethos to the British public schooling system. Schools began expanding their grounds to accommodate a growing sporting culture (Goldblatt, 2006). Various sets of rules were developing and it wasn’t until 1871 that association football became a distinct sport after Sheffield and London based football associations reached an agreement. A short time later, in 1885, the Football Association (FA) of England was forced to allow professionalism in soccer after rivalries between clubs and varsities intensified to such an extent that players were being paid so that these clubs and varsities could ensure the best players would remain loyal to them. The FA released this statement, “It is now expedient in the interests of association football to legalise the employment of professional football players, but only under certain restrictions” (Goldblatt, 2006, p. 47).

Growing interest in the sport lead to increased interest from the press and public and advertisers were not far behind, leading to increasingly larger salaries for players and fees for transferring of players from one club to another. The First World War threatened the rise of soccer in Britain as professional football ceased for the duration of the war. However, the game had spread like wildfire around the world, and while in some countries, like the United States of America and Australia, the game didn’t take off initially, in others it began to thrive and grow in unison with Britain’s colonial rule. After the war, professional soccer in England resumed with renewed vigour. Live radio commentary and endorsements became commonplace in the 1920s, and the rise of the football manager begun.

Herbert Chapman was the central figure in the rise of the football manager. He transformed the job from minimalist training, medical and laundry services into one which encompassed absolute control over team selection, play and tactics (previously done by the players and/or club director) (Goldblatt, 2006). Chapman was able to do so partly because of the force of his personality and partly due to the internal disarray at his current club. Chapman began to experiment with formations in response to the offside rule, and he also began picking players based on their physical attributes so that they could fulfil specific roles on the soccer field. At the same time other managers such as the German, Sepp Herberger, were doing similar things around Europe and the game began to thrive in cities like Vienna, Budapest and Prague.

The foundation of The International Federation of Association Football (FIFA) in 1904 paved the way for international fixtures to take place. Previously, international matches consisted mainly between England and Scotland and later Wales and Ireland. While the First World War, Great Depression and Second World War all halted the progress of FIFA, it was in 1930 that the first soccer world cup was staged and international football grew from strength to strength. Simultaneously, Colombia found its national and club teams unable to compete outside of their own country due to civil unrest – a sanction imposed by FIFA. This lead to Colombian clubs investing heavily in foreign players to create an exciting league within Columbia. By 1950, there were over 100 foreign players playing in Colombia, lured by the large salaries offered by Colombian teams. This was the first time that players began moving cross-continent in search of better paying clubs. After the ban was lifted on Colombia, one of the club teams, Millonarios, had players leaving for Europe as a result of their world tour. These were the early days of international transfer of soccer players. At the same time, in Europe, the first soccer match played under floodlights brought about a "taste of theatrical glamour" (Goldblatt, 2006, p. 397) to the game. With the introduction of a new, exciting format in the UEFA European Cup, the televised broadcasts of games and a new level of affluence in the game brought about by high industrial Europe, soccer was flourishing on the continent.

"European integration and competition and electric floodlights were important in shaping the development of European football, but it was television that would eventually have the most profound impact of all" (Goldblatt, 2006, p. 400).

In the years to follow, new methods of playing and training were beginning to arise and countries and clubs alike began developing specific styles of play. Winner (2012) described the state of Dutch football leading up to the invention of Total Football, stating that the Dutch were tactically years behind the other European nations who had started developing their own specific styles of play. Winner (2012) adds that the 2-3-5 formation used by the Dutch in the post war era resulted in very poor results.

Shortly after this, Dutch football which consisted mainly of players from its greatest club of all time, Ajax Amsterdam FC, began playing a style of football known as 'Total Football'. This revolutionary system of play lead them to the final of the 1974 FIFA World Cup and was driven by members of the great Ajax (Winner, 2012). The success of the Dutch national and Ajax Amsterdam teams respectively, not only in achieving results, but in enthralling spectators coupled with the profound impact of television on soccer mentioned earlier resulted in the establishment of Ajax Cape Town FC in South Africa. Desai (2008) suggested that European clubs took advantage of satellite television to create a global market for soccer players and supporters alike, citing Ajax Cape Town later in his study as an example of a feeder club that aims to provide talented players from another country to the parent club at low cost (i.e. players such as Benni McCarthy and Steven Pienaar).

At the turn of the millennium, soccer players began earning astronomical amounts of money. Goldblatt (2006) uses Winston Bogarde as an example of a player earning 40,000 pounds a week at Chelsea FC on a four year contract, but who played only 12 games for the club. Furthermore, David Beckham's 25 million Euro annual income in 2005 was made up by two-thirds endorsements. Players were becoming leaner and more conditioned than ever owing to the ever increasing pace of the game. Marketing and managing the brand of the football club became top priority to ensure sales, maximise profits and encourage investors to buy into the club. One Real Madrid director stated that they did not buy one of the best players in the world, Ronaldinho, because, “There was no point in buying him, it wasn’t worth it. He is so ugly that he’d sink you as a brand” (Goldblatt, 2006, p.683).

With this amount of money being made, the game demanded increased professionalism and varying training methods to ensure victory that was not only important to players as an achievement in its own right, but to the club for their respective brands. In 1995, Ajax FC won the Champions League under head coach Louis van Gaal. Van Gaal took the total football framework of the 70’s and adapted and refined it for the increasingly demanding and fast paced modern game. The Ajax team worked relentlessly in training using, “complex triangular passing routines and games” (Goldblatt, 2006, p. 714). This was not the first time the small-sided game had been used but it became increasingly important as a method of training. The English Premiership consisted of nearly 60 percent foreign players in 2004 compared to less than 5 percent in 1992 (Goldblatt, 2006). Foreign managers and coaches began to flood into what was then the richest league in the world. Each coach brought their own methods of training and diverse philosophies.

It has been more than a decade since the publication of Goldblatt’s *The Ball is Round: A History of Global Football* and the growth of the game in terms of monetary, professionalism and training tactics has continued to rise. Now more than ever necessitates the in-depth study and review of training tactics within the sport in order to ensure maximal performance in an industry that is becoming increasingly outcome/results driven and cut throat. SSGs are one of a number of training methods employed globally and the processes therein are important to understand to ensure optimal training.

In a study by Davids, Araujo, Correia, and Vilar (2013), SSGs are distinguished against traditional training methods. Davids *et al.* (2013 p. 154) provide an explanation of traditional training methods, "Traditional application of science to team games has emphasized training of specific physiological fitness indices, perceptual skills, and technical or tactical actions through use of repetitive practice drills often performed in isolation from the competitive performance context". They go on to categorise traditional training methods into two categories; part-task training, and adaptive instructions. Davids *et al.* (2013 p. 154) conclude that, "Such traditional methods provide a limited scope for action variability in learners because a key aim of practitioners is to decrease uncertainty of actions and rationalize decision-making processes in training drills". Davids *et al.* (2013) suggest that SSGs have the potential to provide a much increased functional acquisition of performance behaviours in comparison to their traditional training method counterparts in several types of sports. They suggest that, "skill acquisition tasks and evaluation tests in sport development programs need to be pre-dictated on performance in SSGs rather than isolated practice drills in static practice context".

The development of the SSG framework as explained by Davids *et al.* (2013) has lead to many soccer clubs around the world adopting this method of training and indeed Ajax Cape Town FC are one of those clubs. The SSG and 'Total Football' patterns of play lend themselves to one another such that players are able to perform more than one role on the field based on the position they might find themselves in, in both a SSG or match situation.

Aims of the Study

The primary aim of the study was to determine whether the internal training loads of SSGs of varying sizes differed and whether those training demands equated to the demands of competitive matches in soccer. The secondary aim of this study was to determine whether players of different playing positions experienced different internal training and match loads and whether the training demands of different positions equated to those same positions in match play.

Objectives of the Study

The following objectives guided the study:

1. To determine the differences in cortisol responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games.
2. To determine the differences in cortisol responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games in players in different playing positions.
3. To determine the differences in testosterone responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games.
4. To determine the differences in testosterone responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games in players in different playing positions.
5. To determine the differences in T:C ratio responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games, matches, yoyo level II, and resting levels over the duration of the season.
6. To determine the differences in dehydroepiandrosterone (DHEA) responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games.
7. To determine the differences in dehydroepiandrosterone (DHEA) responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games of players in different playing positions.

8. To examine the endocrine response to competitive and friendly match-play amongst the squad as a whole.
9. To examine the endocrine response to competitive and friendly match-play amongst the different playing positions.
10. To determine the endocrine response of the soccer players to the Yoyo Level II test.

Motivation

The motivation for research in this specific field is primarily due to the interest I have in using small sided games as the bulk of content in my soccer training programs. This research will hopefully provide valuable data that can be applied in my work place over the years to come. Two mentors of mine, Warren Engelbrecht and Jose Cabral, although using small-sided games for different outcomes, are both strong supporters of using small sided games as a form of training soccer players of any age and level of play. The two coaches mentioned above are prime examples of how small-sided games can be used to improve fitness throughout the season and alternatively how they can be used as a method of training to improve maximum participation and fun. Small-sided games have a unique characteristic of training technique, tactics and physical fitness simultaneously. It is this unique characteristic that drove my decision to further investigate the effects of the small-sided games on players. The potential to use small-sided games as an alternative to traditional interval conditioning training was the main motivation for the study because this allows players to spend more time on the soccer field with the ball at their feet. This method of training coincides with my coaching philosophy which includes maximum participation by all the players and game oriented training.

Monitoring of training load in soccer, and even more so monitoring internal training load, and the assessment of fatigue and recovery at specified post-game intervals is currently not a priority in soccer. The purpose of this study is to provide valuable information that can help coaches in South African soccer use small-sided games to condition their players optimally for match demands, meanwhile providing sufficient information on fatigue to provide adequate recovery when using small-sided games as a method of conditioning. This study is should also shed light on the hormone responses to training through the monitoring of testosterone, cortisol and DHEA – three hormones which require more analysis in soccer than they are currently receiving. Furthermore, the knowledge gained through testing will provide insight into fatigue on elite u19 players and with it, valuable information in terms of possible recovery strategies and ways to monitor fatigue.

Chapter Two

Theoretical Context

Introduction

This chapter aims to describe the small-sided game (SSG) as a training tool for soccer coaches through the analysis and comparison of various literature that relates to SSGs and soccer training. Prominent authors' work will be studied in depth to provide a more complete understanding of the physical and technical demands and requirements of the SSG. The chapter will be written in a logical manner that will elaborate on each one of the variables which is considered pertinent in this study and provide context for the current study. Variables of; status of training, size of pitch and number of players, competition versus training and playing position will be thoroughly examined with focus on their influence on SSGs. Later on, training load will be analysed with special focus on the difference between external and internal training loads and the relevance of both in the study. The hormonal variables used in this study to monitor internal training load will then be explored, they include; cortisol, testosterone, T:C ratio and dehydroepiandrosterone (DHEA). Each hormone will be discussed with reference to their relevance of determining training load as well as their reliability and validity to do so. Lastly, the issue of recovery and fatigue will be addressed with focus on the SSG context and how this study aims to address recovery and fatigue in the soccer environment.

Small-sided games

Before defining small-sided games (SSGs) and discussing the variables that affect them, it is important to understand the logic behind the idea of SSGs. The old adage 'practice makes perfect' is probably best explained in literary terms by Malcolm Gladwell's 10,000 hour rule. Gladwell states in his book *Outliers* (2008) that in order to reach an expert level in any discipline, one needs a minimum of 10,000 hours of deliberate practice in that field. Gladwell's 10,000 hour rule was formulated from the findings of a study by Ericsson, Krampe, and Tesch-Romer (1993) which aimed to answer the question of why so few people ever reach an expert level of performance in their respective fields (Macnamara, Hambrick, & Oswald, 2014). Ericsson *et al*. (1993) concluded based on their study of musicians that, "high levels of deliberate practice are necessary to attain expert level performance" (Macnamara, *et al.,* 2014, p. 1608-1609).

While slightly outdated, Malcolm Gladwell's 10,000 hour rule does hold some merit when analysing performance in all aspects of life. A recent study at Princeton University showed through meta-analysis that „deliberate practice" accounted for only 18% variance in performance in sport and the authors concluded that while deliberate practice is important – it's importance has perhaps been overstated in the past (Macnamara, *et al.,* 2014). Gladwell himself has recently explained these findings stating that, "I have never seen a boy who was slow become fast" (Gladwell, 2013, p. 3) and concluding that, "In cognitively demanding fields, there are no naturals" (Gladwell, 2013, p. 3). Indeed it is apparent that deliberate practice is of greater importance in distinguishing between elite and amateur performance in areas of life that are less dynamic than the ever changing environment of sport and, specifically, soccer. However, it is important to note that 18% is still a large variance and that without deliberate practice other factors would play a much larger role in distinguishing between performances. In a paper by Jupiter and Gruber (2012, p. 1451) which discusses innovation and the 10,000 hour rule it was stated that, "In innovation, as in any other work, there is talent, there is ingenuity, there is predisposition. But when all is said and done, innovation becomes hard, focused, purposeful work, making very great demands on diligence, on persistence, and on commitment". While these and other factors may make up 82% of performance in sport according to Macnamara *et al*. (2014), it is clear that deliberate practice still has a highly influential role to play in innovation and performance. SSGs discussed below could provide an innovative way of "cheating" the 10,000 hour rule. In a sport that requires a ball, teammates and functioning human to play, there are several aspects that make up „deliberate practice‟ and SSGs seek to practice deliberately all aspects of soccer as opposed to removing individual aspects such as; the ball or ones teammates. Effectively, the author is of the opinion that SSGs have the potential to turn the 10,000 hour rule into the 3,333 hour rule by training at least three aspects of soccer at once.

Defining small-sided games in soccer

Small-sided games (SSGs) are commonly used in many team sports with the aim of improving technical and tactical performance as well as aerobic capacity among players (Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014). SSGs in soccer have been extensively researched with regards to the feasibility of SSGs as a method of aerobic training rather than traditional, interval running, at intensities of 90-95% HRmax (Halouani *et al.,* 2014). SSGs in soccer are a common method of training practised throughout the world for a number of reasons. SSGs are defined by Frauda, Zubillaga, Caro, Fernandez-Garcia, Ruiz- Ruiz, and Tenga (2013) as games played on reduced pitch areas, often using adapted rules and involving a smaller number of players than full-size soccer matches. Hill-Haas, Dawson, Impellizzeri, and Coutts (2011, p. 201) characterize SSGs further as, “modified games played on reduced pitch areas, often using adapted rules and involving a smaller number of players than traditional football games”. The role of the soccer ball in SSGs allows for the unique characteristic of training in the technical, tactical and physiological aspects of performance in soccer. Therefore, SSGs are widely considered to be a suitable tool for soccer training as physical performance, technical skills and tactical awareness can be developed concurrently (Frauda *et al.*, 2013). This viewpoint is supported by many authors who are increasingly studying SSGs in order to determine how this form of training can be optimised. While SSGs were initially imagined as a manner to improve technical and tactical performance, they are being increasingly used as an alternative to interval training as an aerobic training stimulus (Hill-Haas, Coutts, Roswell, & Dawson, 2008; Halouani *et al.*, 2014).

Factors affecting the training outcomes of small-sided games in soccer

Pitch size and number of players

Factors affecting the training outcomes of SSGs in soccer include the training status of the team (i.e. amateur vs elite players), the effect of the size of the playing field, the number of players per SSG, as well as the duration of the SSG (Castellano, Casamichana, & Dellal, 2013; Fanchini, Azzalin, Castagna, Schena, & McCall, 2011). Previous authors suggested that the workload tends to increase as the number of players and relative pitch size decreases. Castellano *et al.* (2013) suggested that this is not always the case as they found that while heart rate demands increased with the decrease in number of players as hypothesized, certain external data such as peak speed and number of accelerations did not, indicating a distinction between internal and external loads experienced by the players.

In a study by Frauda *et al.* (2013) that aimed to compare the individual playing area in competitive games versus SSGs, it was noted that the individual playing area has an effect on both the physical conditioning and tactical performance in both matches and SSGs. Frauda *et al.* (2013) stated that on average, the individual playing area in competitive matches ranged from 78.97 ± 15.05 to 93.87 ± 16.25 m The authors referred to research that indicated that the larger the size of the pitch, the greater the cardiovascular strain becomes. However, the most significant finding of the study was that the tactical element of the game changed significantly when the size of the pitch changed. This is indicative of the unique, multi- faceted character of the SSG. Fradua *et al.* (2013) found that pitch sizes with larger playing areas suit build up and finishing phases of play while smaller pitch sizes are recommended for transition phases of play in the central areas of the field. They go on to recommend widths of fields for SSGs based on their findings which include; 10-30m for 2v2 and 3v3 SSGs, 30- 50m for 6v6 and 7v7 SSGs and 50-70m for 10v10 SSGs. These suggestions further indicate that the relative size of the field must be controlled during SSGs to induce the same demands of competitive match-play.

A schematic representation of the size of an individual playing area in a SSG compared to a competitive match is shown in Figure 2.1. below:

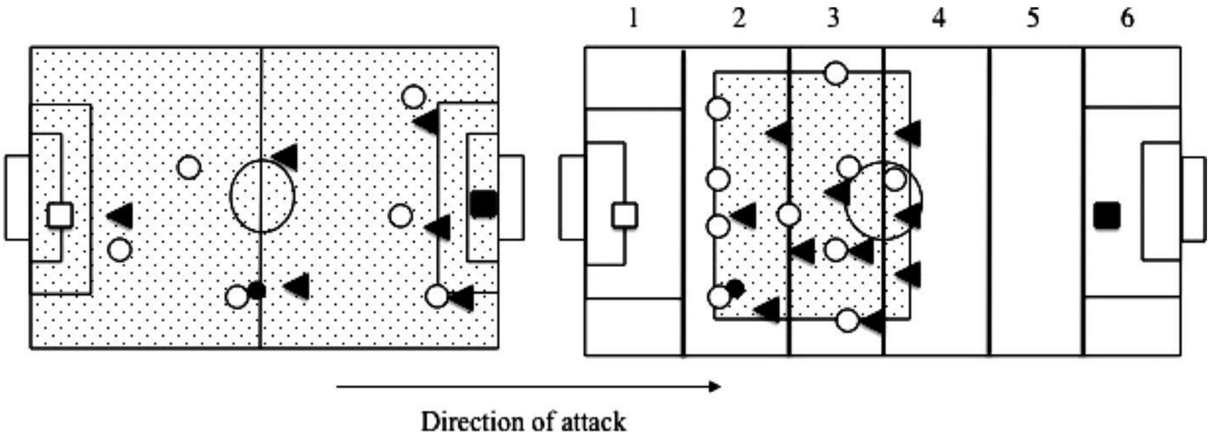

Figure 2-1 A schematic representation of the size of individual playing area in a SSG (right) compared to a competitive match (left). Adapted from Frauda *et al.* (2013, p. 576). (See Appendix E)

Level of participation and competitiveness

Increasing numbers of studies focusing on the level of participation or competitiveness of soccer players are being published including comprehensive work from Abrantes, Nunes, Macas, Leite, and Sampaio (2012) and Casamichana and Castellano (2010). These particular studies revolve around the use of SSGs as a form of training soccer players but differ in many ways. Further studies focus on soccer players of an elite playing level (Dellal, Lago-Penas, Wong, & Chamari, 2011; Owen, Wong, Paul, & Dellal, 2012) while others include players of lower playing levels or at youth level (Dellal, Hill-Haas, Lago-Penas, & Chamari, 2011; Dellal, Varliette, Owen, Chirico, & Pialoux, 2012).

In a comprehensive study by Dellal *et al.* (2011) amateur soccer players were compared to professional soccer players in terms of their technical, physiological and physical responses to SSGs. The study used SSGs of varying sizes (2v2 – 4v4) and proportionate pitch sizes to monitor and compare heart rate response, blood lactate response, rating of perceived exertion, technical performance, physical performance and lower body performance after the

SSGs. Upon comparing running patterns, Dellal *et al.* (2011) concluded that amateurs covered significantly less total distance, sprinting distance and distance in high intensity running than their professional counterparts during the SSGs.

In addition to these running patterns, technical elements were significantly worse from the amateur players including pass success rate and loss of possession of the ball and certain physical and physiological variables such as RPE, blood lactate concentration and performance in the squat jumps and counter-movement jumps post-SSG. Heart rate response was very similar for both groups across all formats of SSGs indicating, in conjunction with blood lactate and RPE scores, a high level of internal training load for both the amateur and elite athletes.

The studies mentioned above indicate that SSGs are being used as training method around the world in different age groups and at different levels of training. The study by Dellal *et al.* (2011), indicated that while amateur players do not perform SSGs to the same level as professional players, the SSG format can be of great benefit for both the amateur soccer player as well as the professional soccer player. It was suggested that the amateur's inferior technical abilities and training status affected their performance in the SSGs. Dellal *et al.*, (2011, p. 2380) concluded that, "Finally, this method of training closely replicates the physical and technical match-play conditions for professionals and constitutes a useful training tool for the elite soccer coach".

In order to address the issue of whether or not SSGs are truly useful as a training tool in soccer, it needs to be determined whether the demands of SSGs mirror those of actual soccer matches. Kelly, Gregson, Reilly, and Drust (2013, p. 938) stated that "the principle of specificity suggests that training effects are limited to the pattern of muscular involvement that is incorporated in the conditioning exercises that are performed". This statement alludes to the fact that exercises during training should be as closely related to those performed during match-play. Kelly *et al.* (2013) further suggested that the inclusion of a soccer ball during training should, under this hypothesis, allow for more specific muscle recruitment patterns and increase in energy expenditure while training.

In an attempt to discover whether SSGs truly prepare soccer players for the demands of a match, Casamichana, Castellano, and Castagna (2012) compared friendly match-play against opposing teams to SSGs amongst semi-professional soccer players. They found that the two formats stressed the players differently with friendly matches providing a greater stimulus for high-intensity efforts such as sprinting. However, the overall workload was found to be higher during SSGs with more time spent at medium-intensity running. They further suggested that SSGs be compared with competitive matches rather than only friendly matches, which will allow for a truer representation of the SSG to competitive match relationship.

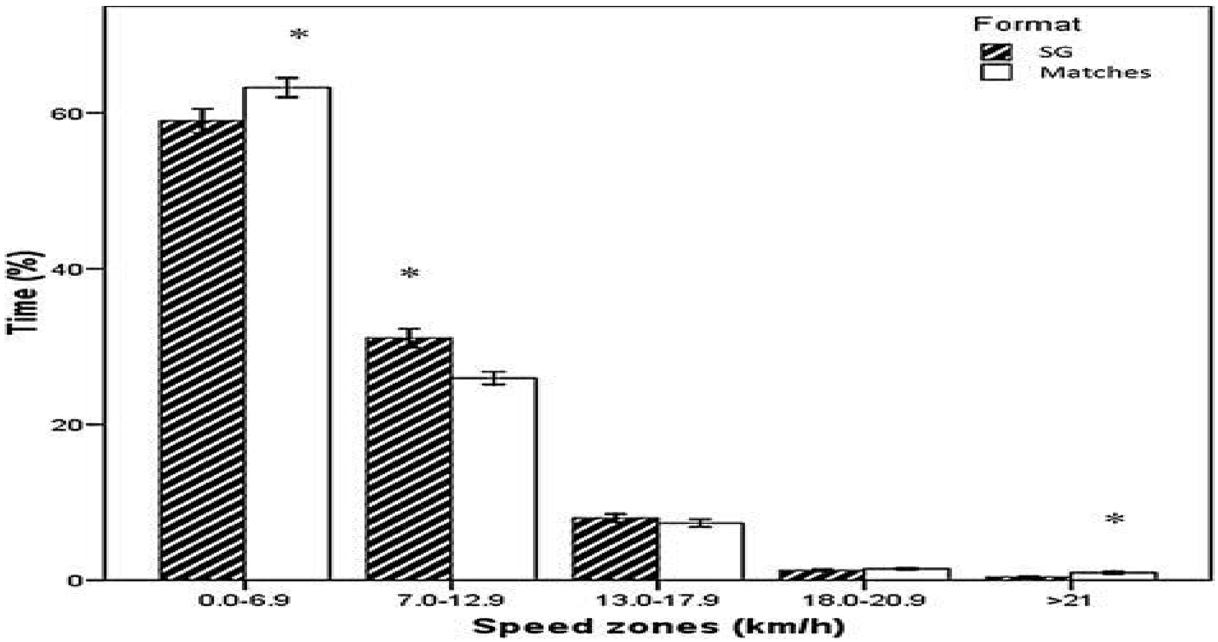

Figure 2-2 Schematic representation of percentage of time spent in different speed zones in small-sided games compared to friendly matches. Adapted from Casamichana *et al.* (2012, p. 840). (See Appendix E)

Playing position

Di Salvo, Baron, Tschan, Calderon Montero, Bachl, and Pigozzi (2007, p. 222) stated that, ”Understanding the physiological load imposed on top-level soccer players according to their positional role during competitive matches (activity profile, distance covered, intensity, energy systems and muscles involved) is necessary to develop a sport specific training protocol”. This statement reinforces the notion of training specificity which applies not only to the team in the soccer environment, but to the positional role of individual players as well. In an analysis of over 300 players over 30 highly competitive matches, Di Salvo, Pigozzi, Gonzalez-Haro, and De Witt (2013) discovered that midfielders cover a significantly greater distance over the course of a match than both the defensive and attacking groups and that central defenders cover the least total distance of any subgroup. Furthermore, central defenders were found to spend more time walking and jogging than any other subgroup, but significantly less time moving at any of the higher exercise intensities. Results like these, along with findings like those of Bangsbo and Michalsik (2002), who found that midfield players had the highest $VO_{2\ MAX}$ of any other playing position, further necessitate the need for training to mirror the match environment (Spinks, Reilly, & Murphy, 2002). It is hypothesized that the nature of SSGs allows for this mirroring to occur naturally because of the specific roles of each position having to be filled as they are in match-play.

Dellal *et al.* (2012) stated that position specific requirements vary considerably during match-play in elite soccer, suggesting that these specific requirements can be catered for by position specific training methods. They posit that previous research found significant differences between variables such as high intensity running, number of sprints, and total distance covered among players in different playing positions during match play. However, research of their own showed insignificant differences in terms of playing position and variables of total distance covered, total distance covered at high intensity and total distance covered while sprinting in 4v4 SSGs. These findings suggested that while 4v4 SSGs mirror the technical and physical demands of match play, they do not exactly mirror the physical demands of elite match play within specific playing positions. While these findings are in contrast to the previously mentioned hypothesis, the findings of this study will further aide research in this matter.

Other factors

Several other factors affect the training outcomes of SSGs including; the effect of goalkeepers on SSGs (Koklu, Sert, Alemdaroghi, & Arslan, 2014), the effect of defensive/ marking styles (man-to-man versus zonal defensive systems) (Ngo, Tsui, Smith, Carling, Chan, & Wong, 2012), and even the influence the number of touches each player is allowed on the ball before having to pass (Dellal *et al.*, 2011) has been investigated which further indicates the quality and amount of research currently being done in the SSG context.

Koklu *et al.* (2014, p. 968-969) illustrated the confounding nature of the goalkeeper perfectly when they concluded while greater physiological responses (significantly higher %HRmax, RPE and blood lactate concentration) and larger distances were covered in their study assessing SSGs without goalkeepers that, “players may be more motivated in SSG with goalkeepers compared with SSG without goalkeepers because they could do more game-based actions such as shoot or crosses during SSG with goalkeepers). Ngo *et al.* (2012) found that man-to-man marking significantly increased the HR response of all players competing in SSGs compared to zonal marking and suggested that SSG intensity levels could thus be controlled through defensive systems. Even the number of touches on the ball before having to pass – a rule implemented by the coaches – has an effect on the intensity of SSGs. Dellal *et al.*, (2011) suggested that this rule needs to be closely monitored when designing SSG programs.

Summary

The purpose of listing and explaining the variables affecting the training outcomes in SSGs in the first part of the theoretical context above is to provide the reader with insight into the complex nature of the SSG environment. All of the factors mentioned above make controlling training outcomes in a SSG environment extremely difficult, however, the benefits of SSG training are also made clear and the correct execution of SSG training can yield significant physiological adaptation.

Monitoring Training Load

Rebelo, Brito, Seabra, Oliveira, Drust, and Krustrup (2012, p. 297) stated that, "the monitoring of training load is a key factor for the control of the training process in sport". They suggest that training load needs to be accurately evaluated in order to plan and periodise future training sessions and further suggest that monitoring training load is crucial in the prevention of both under and overtraining and allowing for the optimal conditions for training adaptation. In order to determine the physiological effects of SSGs on soccer players, the training load on the body must be measured.

Training load can be divided into external and internal load. External load is quantified, among others, by the distances and acceleration forces that a player incurs while training and internal load is quantified through the hearts response to these external factors as well as the players perceptions of fatigue (Casamichana, Castellano, Calleja-Gonzalez, San Roman, & Castagna, 2013).

External training load

A popular measurement tool for soccer specific endurance due to its intermittent nature is the Yo-Yo intermittent endurance recovery test level two (yoyo2). The yoyo2 measures external load directly through monitoring distance covered over time, and indirectly it measures internal training load when used in conjunction with heart rate monitors and RPE scales.

A study by Bradley *et al.* (2011) which monitored 148 elite and 14 sub-elite male soccer players during a yoyo2 found it to be a sensitive tool relating to match performance and able to differentiate between intermittent exercise performance of players of various standards and positions and in different stages of the season. These findings were in line with previous research that found the yoyo2 reproducible, able to discriminate between playing positions and standards and correlating with match performance (Bangsbo, Iaia, and Krustrup, 2008; Saunders, Sunderland, Harris, & Sale, 2012).

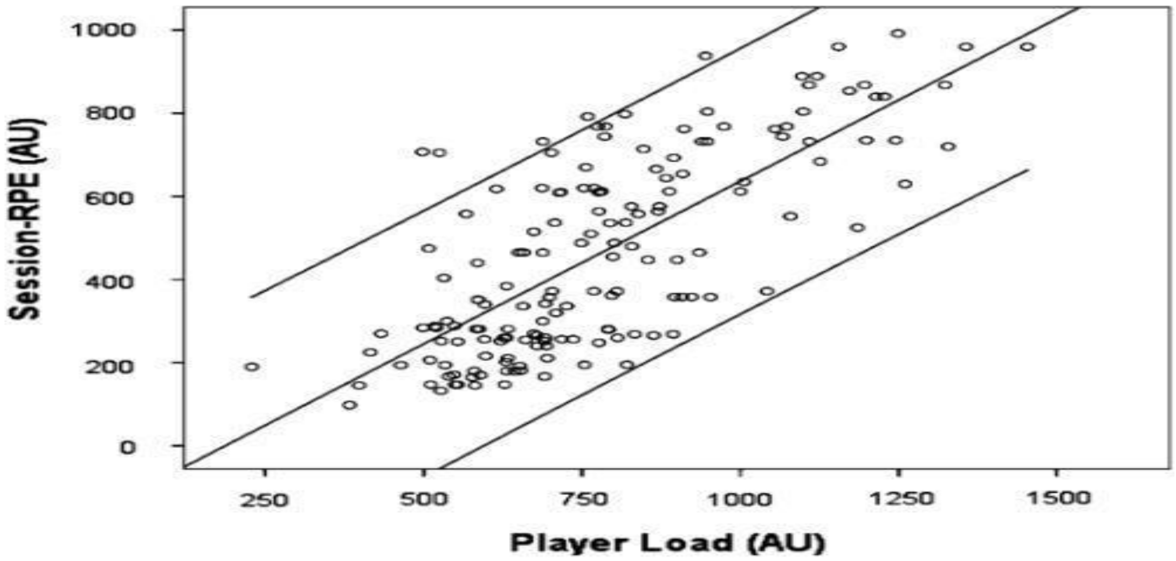

Figure 2-3 A schematic representation of a very strong correlation between internal (sRPE) and external (player load) training loads on the body. Adapted from Casamichana *et al.* (2013, p. 372). (See Appendix E)

Impellizzeri, Rampinini, Coutts, and Marcora (2004) argued that while external load is commonly used to assess training outcomes through physical tests (such as the yoyo2), it is the internal training load rather, that is the stimulus for adaptation through training. Therefore, it is equally important to monitor internal training load as it is to monitor external training load. The most common methods of monitoring internal training load in soccer players include heart rate measurement and rating of perceived exertion (Alexiou & Coutts, 2008). These two variables have been extensively examined independently and in relation to external loading data, however, a much less used method of determining internal training load is through the measurement of the endocrine response to training.

Internal training load

Cortisol, testosterone and dehydroepiandrosterone (DHEA) have all been used to monitor endocrine responses to a stimulus in general training environments. These three adrenocortical hormones can be recorded and measured either as serum or saliva samples. Saliva samples offer a convenient, non-invasive way to determine adrenocortical hormone concentrations at rest with the added benefit of being positively correlated with serum adrenocortical hormone concentrations (Thomasson, *et al.*, 2010). However, there is doubt over the correlation between serum and saliva adrenocortical hormone measurements during and following physical exertion. Thomasson *et al.* (2010) found that there is a correlation between serum and saliva values of cortisol and DHEA and suggest that saliva adrenocortical concentrations can be used as a reference for their respective blood concentrations in response to submaximal exercise. According to Moreira, Arsati, Arsati, Silva, and de Araujo (2009), salivary diagnosis is an increasingly important field in physiology and endocrinology amongst other fields. Salivary composition is influenced during exercise by the autonomic nervous system and hypothalamic-pituitary-adrenal axis. Moreira *et al.* (2009) suggested that salivary steroids are in equilibrium to those of the blood and that in certain ways, saliva cortisol may provide a better measure of cortisol than that of its serum counterpart owing to the non- invasive nature of collection.

Biomarkers used for monitoring internal load

Cortisol

Cortisol is a catabolic (muscle breakdown) steroid hormone, known as “the stress hormone” which has been shown to increase in concentration after exercise in almost all sporting codes regardless of genotype, age or sex including in soccer (Edwards *et al.*, 2006; Pimenta, *et al.*, 2012; Banfi & Dolci, 2006; Lippi *et al.*, 2009). Cortisol has been shown by Van Bruggen *et al.* (2011) to present similar effects when analysed amongst serum and/or saliva (ideal saliva assay at 30min post exercise). It is suggested by Duclos, Guinot, and Le Bouc (2007) that prolonged increase or decrease in cortisol concentration can have adverse effects on an individual. Cortisol is produced by the adrenal glands functioning in the modulation of blood pressure, cardiovascular function and the regulation of metabolic substrates and immune system (Lippi, De Vita, Salvagno, Gelati, Montagnana, & Guidi, 2009). The secretion of cortisol undergoes diurnal variation with highest concentrations experienced in the mornings and lowest at night time. Furthermore, cortisol is released in response to stress on both a physical and psychological scale which accounts for the increase in the measurement of cortisol to determine the stress of training.

A study by Moreira *et al.* (2009) showed that while many hormones and adrenal glucocorticoids are released as an adaptation to either physical or psychological stress, cortisol is probably the most affected. This finding is indicative of the amount of research based on cortisol release during activity (Edwards & Wetzel, 2006; Banfi & Dolci, 2006; VanBruggen, Hackney, McMurray, & Ondrak, 2011; Labsy, *et al.*, 2013). The study goes on to state that the nature of the game of soccer and the physical demands of soccer should stimulate a change in cortisol levels during training and match environments. Soccer is described by Moreira *et al.* (2009) as a sport characterized by periods of high-intensity activity including sprinting, jumping and tackling followed by lower intensity actions such as jogging or walking. Furthermore, soccer is described as an intermittent sport with periods of active and passive recovery. While physical stress has been shown to change levels of cortisol in the body, no literature has been found that attempts to answer whether any significant changes can be found between small sided games of varying sizes. Each small sided game has a different external loading profile with regards to time of play, size of field and number of players, therefore it is hypothesized that the internal response to these various games will mirror those of the external load.

Testosterone

Testosterone is an anabolic (muscle building) steroid hormone which shows varying concentration levels in many sporting codes. In soccer it is suggested to increase in men and women immediately after competitive match play (Edwards *et al.*, 2006) while Bouchard, Blair, and Haskell (2007) state that testosterone concentration is elevated after exercise. However, conflicting reports suggest that after eccentric training, testosterone decreases in concentration (Pimenta *et al.*, 2011). Results are mixed in terms of what the acute response to soccer training is with regards to testosterone concentration. Testosterone, much the same as cortisol, is a hormone important in defining adaptive response to training in competition according to (Banfi & Dolci, 2006). However, where cortisol concentration is indicative of muscular catabolism or breakdown, testosterone concentration is indicative of muscular anabolism or building. The two hormones are often measured together in an attempt to study and prevent overreaching and overtraining. The ratio between the two can provide an indication of overtraining, which is to say that the concentration of the catabolic hormone far outweighs that of the anabolic hormone. Banfi and Dolci (2006) go on to state that the ratio between these two hormones is known as the free testosterone/cortisol ratio (FCTR), where free testosterone is defined as testosterone not linked to any proteins.

Edwards, Wetzel and Wyner (2006) found that both levels of cortisol and testosterone were substantially higher for men after they played a soccer match than compared to beforehand. Furthermore, the authors suggest that testosterone levels in men are reportedly related to faster reaction time and better spacial perception - two attributes that could potentially improve performance on the soccer pitch. Moreira *et al*. (2009) stated that testosterone has a key role in determining functional performance in young soccer players. Testosterone concentration was identified as a key indicator of explosive performance in the mentioned study rather than intermittent endurance performance. It is therefore suggested that testosterone has clear relationships with both overtraining and performance worth investigating, both on its own, and in relation to cortisol concentration.

Dehydroepiandrosterone (DHEA)

DHEA or dehydroepiandrosterone is defined by Savineau, Marthan, and de la Roque (2013, p. 718) as a, "steroid hormone derived from cholesterol synthesized by the adrenal glands". The recording/measurement of DHEA traditionally functions for several different reasons, other than determining training load in sport, including; insulin resistance, cancer, reduction of the immune defence system, Alzheimer's disease, depression and cardiovascular disease (Savineau *et al.*, 2013). However, more recently, researchers have begun to investigate the relationship between DHEA concentration and the effects of training load/ match demands in varying sports (Collomp, Buisson, Lasne, & Collomp, 2015). Collomp *et al.* (2015) state that DHEA is preferred to dehydroepiandrosterone sulphate (DHEA-S) because of its shorter elimination half-life which makes for an improved measure of the acute response to exercise. They conclude that correlation between saliva and serum concentration is high for steroid hormones at rest and during exercise which, adding to its non-invasive collection, makes the saliva sampling process ideal for the testing of athletes which is in line with the findings of Van Bruggen *et al.* (2011) who reported a correlation between serum and saliva cortisol ($R = 0.73$; $P = 0.001$).

DHEA is another adrenal hormone, similar to cortisol, which can be reliably measured in saliva and is highly correlated with total hormone blood levels and with free hormone concentration in plasma (Ponzi, Muehlenbein, Sgoifo, Geary, & Flinn, 2015). DHEA's role in the physiology of the body is far more unclear than that of testosterone and cortisol, however, it is the most abundant circulating androgen in the body and is known to be released during periods of acute psychosocial stress (Ponzi *et al.,* 2015). Furthermore, DHEA has been shown to follow a similar diurnal pattern of release to that of cortisol, however it does not tend to spike as cortisol does upon awakening and it is far more stable throughout the day when compared to cortisol (Ponzi *et al.*, 2015). With regards to exercise, DHEA has been shown to increase significantly during intense exercise much the same as cortisol (Labsy *et al.,* 2013).

From the above literature it is hypothesized that the three hormones cortisol, testosterone and DHEA will be accurate indicators of stress induced through SSGs, friendly matches and competitive matches in soccer. This monitoring of acute stress could prove useful in determining the adaptation to training as well as monitoring of acute stress and overtraining after practices and matches. It is important to measure the hormones at the same time of day when testing to account for changes in resting levels of the hormones due to the circadian rhythm of the body.

T:C Ratio and Fatigue

Duclos *et al.* (2007) state that T:C ratio is at its highest during sleep which is when muscle synthesis occurs and adaptation to exercise occurs. Conversely, during and immediately post exercise, there is a decrease in T:C concentration as cortisol concentration spikes during stress (training/exercise). The T:C ratio is commonly used in isolation or amongst other variables as a marker of overtraining where chronic low T:C ratio is an indicator of overtraining (Van Bruggen *et al.,* 2011).

Lastly, the issue of fatigue and recovery in soccer is important when attempting to maximise the performance of individuals and the team as a whole. Fatigue occurs as a result of either central or peripheral factors, however minimal research has addressed the issue of the relative contribution of each separate system to fatigue (Rampinini, Bosio, Ferraresi, Petruolo, Morelli, & Sassi, 2011). Additionally, adequate recovery time for fatigue induced by these factors can range from a matter of hours to as many as three days after a soccer match (Nedelec, McCall, Carling, Legall, Berthoin, & Dupont, 2014). Nedelec *et al*. (2014) stated that common match events such as; acceleration, deceleration, contacts with players, jumps and tackles further contribute to muscle damage in players. However, due to lack of research in SSGs, it is yet to be discovered whether the high intensity and close proximity nature of SSGs will cause more peripheral and central fatigue and muscle damage than a full field game of the same length. Resting levels of cortisol and testosterone or the free testosterone/cortisol ratio (FCTR) have been used in various sports to monitor overtraining (Banfi & Dolci, 2006). In a study by Banfi and Dolci (2006), 32 professional soccer players were monitored over a two year period and it was concluded that the FCTR could be usefully applied to soccer to monitor and prevent chronic overtraining. This view is supported by Alexiou and Coutts (2008) who suggested that long-term monitoring of training loads may assist coaches in controlling the training process and assist in improving performance.

Summary

To the author’s knowledge, no research has been published on SSGs in a South African context. Additionally, most articles neglect or reject the effects of fatigue and recovery on soccer players" performance in both the acute and chronic environments and the value that such data could play in optimising performance. There is a particular lack of research on fatigue and recovery in the SSG context and insight as to how SSGs fatigue players and the implications this has on recovery strategies. The amount of literature focused on the monitoring of internal training load in soccer players is scarce which could be due to the fact that the samples require extensive testing processes, the samples are expensive to analyse and that players are not open to the relatively invasive from of testing (either through blood or saliva sampling). However, these hormones could provide insight into the internal loading and adaptation to the stressors of SSGs and matches. The levels of the various hormones could provide insight into how to go about addressing training and recovery protocols for the team as a whole and the players in their specific positions.

Chapter Three

Methodology

Introduction

Owing to the lack of contemporary literature published in South Africa on small-sided games in soccer and the internal loading patterns of such games, there is a great need for studies that aim to investigate the many aspects relating to these games. This chapter aims to describe the study design used and provide an outline as to what and why these procedures took place. Such procedures include the recruitment process which resulted in the final study sample, as well as the ethical guidelines and procedures that were adhered to. Furthermore, an informative and sequential description of how the testing procedures were implemented will be detailed with a description of the saliva sampling method. All tests and measurements performed throughout the study period will be described in this chapter. In conclusion, the outcome variables of the study and the statistical methods that were used to analyse these variables will be discussed.

Experimental Procedure

This study took place in both open and controlled environmental settings. Bickman and Rog (2009) suggested that applied research (open environmental setting) can take place in many different settings - including the place of work - which in this study's case is the training complex where Ajax Cape Town Football Club practices. Meanwhile, basic research (controlled environmental setting) is generally within the researcher's control and subject to close monitoring by the researcher which, in this study's case, is Synexa Life Sciences Pty (Ltd) where hormone analysis was completed. Bickman and Rog (1998, p. XIII) stated that "a key difference between applied research and basic research is the relative emphasis on internal and external validity." They go on to say that while internal validity is vital to both applied and basic types of research , external validity holds much more importance in applied research. Indeed many studies focused on small sided games in soccer have external validity high on their agendas with the aim of producing generalizable results about small sided games. Common aims of SSGs in soccer include: what effects SSGs have on players" heart rate and physical demands (Castellano, Casamichana, & Dellal, 2013), comparing SSGs to more conventional high intensity intermittent training (Dellal *et al*., 2012), comparing the physical demands of SSGs versus match-play (Casamichana, Castellano & Castagna., 2012), comparing response to SSGs based on playing level (Della *et al*., 2011), and determining the relevance of SSGs as a form of training in soccer (Clemente, Couceiro, Martins, & Mendes, 2012). All of the studies above aim to produce results with high external validity that will not only shed light on SSGs with regards to their true effects but allow those findings to be generalized, providing significant findings for coaches around the world using SSGs in their training programs.

Study Design

This study follows a descriptive research design in that it aims to provide a picture of something that occurs naturally rather than studying the impacts of an intervention (Bickman & Rog, 1998). The researcher aimed to provide Ajax Cape Town FC with meaningful information about their training methods as they occurred naturally, without intervention. The reason this study design was chosen linked strongly with Ajax's deep rooted emphasis on

SSGs as a form of physical training. The fact that Ajax had a functioning training system in place which revolved around the use of 4v4, 7v7, and 11v11 SSGs made the necessity of an intervention null and void. This existing training system had an effect on the sampling method used in this study, namely purposive sampling, because the researcher approached Ajax Cape Town FC with the understanding that this training system was in place added to the knowledge that Ajax Cape Town are the most elite soccer club in the Western Cape of South Africa. This study was longitudinal in nature as the researcher linked responses of particular players over the time frame of eight months giving each player a unique code as an alias (Bickman & Rog 1998).

Participants

Description

22 participants voluntarily took part in the study and their ages ranged from 16 years old to 23 years old. Participants were divided into subcategories based on their positions; goalkeepers (n = 4), defenders (n = 7), midfielders (n = 5), and attackers (n = 6).

Recruitment

Participants were recruited through the coaching staff of Ajax Cape Town. Members of the Ajax u19 squad were approached via email to participate in the study and a time was arranged to sit down and meet with the performance staff of the team. In the meeting the aims and methods of the study were discussed and upon later approval from both the coaching staff and performance staff, the study was cleared to go ahead (see Appendix A and Appendix B). It was made clear to each participant in the language of their choosing that participation in this study was completely voluntary and that every participant had the option of withdrawing from the study at any time and without notice. Each player over the age of 18 years old signed an informed consent form and players under the age of 18 years old had their parent/legal guardian sign an informed consent form allowing their participation in the study.

Inclusion and exclusion criteria

Players were included in the study if they a) were men under the age of 23 years old; b) were members of the u19 Ajax Cape Town Football Club; and c) participated in training with Ajax's u19 squad for a continuous period of a month or more. Players were excluded from the study if they a) had a metabolic disease and b) picked up an injury that excluded them from training for six weeks or more during the study (Koundourakis, Androulakis, Malliaraki, Tsatsanis, Venihaki, and Margioris, 2014).

Procedures

Data Collection

Pre-season hormone testing

Upon approval from the coaching staff and performance staff, a date was arranged to perform initial testing. Initial testing involved the explanation of the procedures as well as a summary of the study to both players and staff members of Ajax's u19 team. The players were asked to sign a consent form (Appendix A) and, once signed, the players each provided the researcher with a saliva sample. This sampling took place before training (at rest) so as to establish a baseline to work from in comparisons with the 11v11, 7v7, 4v4 and friendly match which took place in the same time period (pre mid-season break).

The players had not practiced with Ajax the previous day and all players were instructed to inform the researcher about any supplements they might have been using in their individual capacities. This initial saliva sample was taken at 3pm, just prior to training to try and avoid the effects of the circadian rhythm as documented by Labsy *et al.* (2013) with regards to future samples that would be provided between 5-6pm. A total of 22 players consented to and provided saliva samples at the initial testing. Saliva production was un-stimulated and players were only allowed to swirl water in their mouths immediately prior to providing the samples (Labsy *et al.*, 2013). Players used a straw to spit saliva into a test tube which was sealed after reaching 75% or more capacity as instructed by the chief immunologist at Synexa Life Science. The researcher watched the players to prevent players from cheating. The test tubes were immediately sealed and placed on ice and frozen (-18° C) at the researcher's home until delivery to Synexa Life Science's laboratory. The time the samples spent on ice varied from days to weeks long as the Synexa lab preferred to be given a minimum of 30 samples at once for analysis. Therefore, the researcher had to keep samples on ice for varying amounts of time based on the number of samples provided at any given testing session.

11v11, 7v7 and 4v4 SSGs and Friendly Match

Upon completion of the 11v11, 7v7, and 4v4 training sessions and the friendly match (or upon substitution), up to 11 players chosen at random (based on which players took the field on any given training day) provided saliva samples immediately and were instructed to fill their test tubes within thirty minutes. Saliva production was not stimulated, however, players were allowed to swirl water in their mouths before providing the saliva sample. The researcher watched the players to ensure no cheating took place and once the test tubes were 75% full or more, the researcher sealed them and placed them on ice. The completed samples were frozen at the researcher's home until delivery to Synexa Life Science's laboratory. Players had not trained with Ajax the previous day and were asked to come forward about any supplements they may have used in the last 24 hours. This sample collection took place at 6pm. The SSG sessions took place over three two week periods with 11v11 collection occurring in late September, 7v7 collection in early October and 4v4 collection in mid-October. The reason behind this was based on the existing 11v11, 7v7, 4v4 format of training at Ajax with each SSG format lasting two weeks.

Post-season hormone saliva sampling

This sampling took place before training/at rest so as to establish an end of season baseline to work from in comparisons with the Yoyo Level II Intermittent Endurance Test and the competitive match which took place in the same time period as the end of season baseline (post mid-season break). The end of season baseline also provided comparison to the pre-season baseline allowing for a more longitudinal study. The players had not practiced with Ajax the previous day and all players were instructed to inform the researcher about any supplements they might have been using in their individual capacities. This saliva sample was taken at 3pm, just prior to training to try and avoid the effects of the circadian rhythm with regards to future samples that would be provided between 4-7pm.

Match-play and Maximal Testing Characteristics

Two matches and a YoyoII test were completed at various points in the season. The first match (FRIE) was a friendly match that took place in the first half of the season, before the Christmas break. The second match (COMP) was a competitive match that took part in the second half of the season, after the Christmas break. The maximal testing sessions comprised of a YoyoII that took place in the second half of the season, after the Christmas break.

Importantly, there are two baseline (resting) readings for each player in the study, one was taken at the beginning of the season (PRE) against which the FRIE match was compared, and one was taken near the end of the season (END) against which the COMP and YOYO were compared. The two baselines provide a longitudinal aspect to the study for comparison, too.

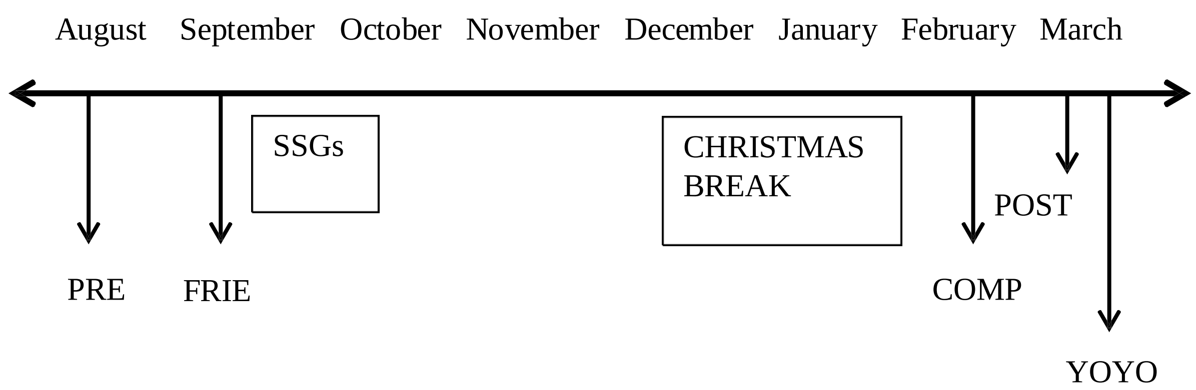

Figure 3-1 Timeline describing the longitudinal aspect of the study.

Table 3-1 Written description of which match, performance testing, and baseline testing points took place on what dates.

SESSION:	DATE:
Baseline Beginning Season (PRE)	12 August 2014
Friendly Match (FRIE)	05 September 2014
Competitive Match (COMP)	13 February 2015
Baseline End Season (POST)	02 March 2015
Maximal Yoyo Level II Test (YOYO)	02 March 2015

Performance Test

Yoyo II testing

The Yoyo II test took place immediately after the end of season baseline saliva sample. Upon completion of the Yoyo level II test, players provided saliva samples immediately and were instructed to fill their test tubes within thirty minutes. Saliva production was not stimulated however players were allowed to swirl water in their mouths before providing the saliva sample. The researcher watched the players to ensure no cheating took place and once the test tubes were 75% full or more, the researcher sealed them and placed them on ice. The completed samples were frozen at the researcher's home until delivery to Synexa Life Science's laboratory. Players had not trained with Ajax the previous day and were asked to come forward about any supplements they may have used in the last 24 hours. This sample took place at roughly 4pm.

Competitive match

Upon the completion of the competitive match or substitution of the player by the coach resulting in the completion of that particular players" match, saliva samples were provided immediately and players were instructed to fill their test tubes within thirty minutes. Saliva production was not stimulated however players were allowed to swirl water in their mouths before providing the saliva sample. The researcher watched the players to ensure no cheating took place and once the test tubes were 75% full or more. The researcher sealed them and placed them on ice. The completed samples were frozen at the researcher's home until delivery to Synexa Life Science's laboratory. Players had not trained with Ajax the previous day and were asked to come forward about any supplements they may have used in the last 24 hours. This sample took place at 7pm.

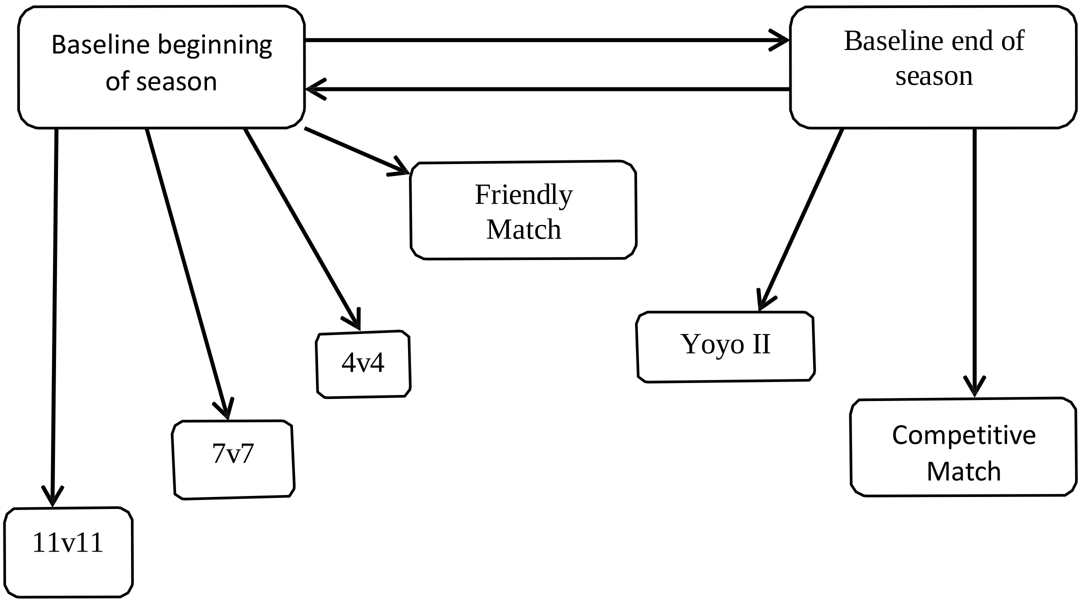

Figure 3-2 Graphical illustration of the data collection procedures indicating which matches, training sessions, and performance tests were compared against which baseline measures. Baseline measures were also compared against one another.

Ethical Aspects

The study protocol was approved by and carried out in a manner that conformed to the principles set out by the Ethics Committee of Research Subcommittee A at Stellenbosch University (Appendix C). Informed consent forms (Appendix A) were handed out in person to all players in the u19 Ajax Cape Town Soccer Team during the initial meeting at Ajax's training premises. Informed consent was explained to each participant in either English or Afrikaans depending on their preference and the aims and outline of the study were explained to the group as a whole. Players were encouraged to ask questions about the study should they have any doubts or fears. Players were informed that the study was completely voluntary and that, at any stage, they may refuse to provide samples or withdraw from the study completely without any justification or negative consequences with regards to their status within the squad. Players were encouraged by their coaching staff to participate in the study which is noted as a limitation of the study later on in text. All of the participants signed their consent forms. This study did not involve any invasive procedures, nor presented any serious risk other than the risk that normal soccer training and matches inherently possess. Saliva samples were chosen specifically for this reason as opposed to serum samples which involve the use of needles (VanBruggen *et al.,* 2011). All of the information obtained during the study was strictly confidential and was not disclosed. All samples, documentation and data obtained throughout the study were handled strictly by the specific player, the researcher, and the laboratory technician at Synexa Life Sciences Pty (Ltd). The documents and saliva samples were filed and stored at the home of the researcher behind locked doors to which only the researcher had access. The saliva samples later became available to Synexa Life Sciences for analysis. Electronic copies were saved on a password protected personal laptop and on an external drive which were only accessible to the researcher. All data used for analysis was safely and securely stored upon completion of the study.

Conflict of interest statement

There were no conflicts of interest during this study. No financial assistance was received from Ajax Cape Town Football Club, or Synexa Life Sciences Pty (Ltd). Synexa Life Sciences provided the hormonal analysis at a fair rate, including an additional hormone analysis free of charge. Stellenbosch University Sport Science Department partly funded the expense of the saliva samples' analysis while another part was personally funded by the researcher.

Measurements and Tests

The aim of this section is to outline the protocols used during the study which were needed for the purpose of measuring and testing the various outcome variables of the study. The protocols were chosen based on the studies of recent, published research and the protocols used in those research studies. The section ends with an explanation of how the data was recorded.

Saliva Samples

Participants were gathered immediately after training, competition, or at rest and received their own plastic packet which included a small test tube and a straw. On each packet was a code which consisted of the player's squad number and initials - to help identify the specific participant - as well as the date of that specific saliva sample. Each participant was instructed to fill their test tube with saliva, using the straw to ensure that they did not mess on the test tube. Once the participants had filled their respective test tubes to at least 75% full, they were asked to close the test tube themselves, characterised by a clicking sound, place the test tube in the packet they received and seal the packet and place it into a cooler box filled with ice. Each participant was instructed to dispose of their own straw in a sanitary manner and this protocol allowed the researcher to have no physical contact with the saliva of any participant. Importantly, each saliva sample was provided within 30 minutes upon completion of exercise, and was taken at roughly the same time of day (either late afternoon or evening), and each saliva sample was not a stimulated saliva sample. Stimulated saliva sample is described by VanBruggen *et al.* (2011) where participants chewed on paraffin film to stimulate the salivation response. The participants in this study protocol were informed that they may swirl and spit out a small amount of water if their mouths were extremely dry, but they were not allowed to eat or drink anything immediately prior to providing their saliva sample.

Once placed on ice, the saliva samples were immediately moved to the researcher's home and stored at below freezing temperature in a deep freeze with an emergency generator in case of power outages. Samples were bunched in order of dates and once a minimum number of 30 saliva samples were obtained, they were transported to Synexa Life Sciences Pty. Ltd in Montague Gardens (Cape Town) in a cooler box. Synexa Life Sciences used liquid-liquid (LL) extraction on an Ultra-High-Performance Liquid Chromatographic Method (UPLC) with Mass Spectrometric (MS/MS) detection to analyse the saliva samples (see Appendix B for full explanation). The specific coding and results were kept on personal, access controlled, computers/laptops of both the researcher and Synexa Life Sciences. Lastly, each day/session in which saliva samples were recorded followed a day where no soccer training took place at Ajax Cape Town FC for the u19 squad. These days are termed as 'rest days' where participants were instructed by their coaches not to perform exercise to allow for recovery and the positive adaptation to their training programs.

Yoyo II Test

A Yoyo II test was performed on March 2nd 2015, prior to which the participants provided a saliva sample at rest and after the completion of the test in which they provided a saliva sample as per the protocol stated above. The actual Yoyo II test was performed as per the standardised Yoyo II protocol (Bradley *et al.*, 2011) as illustrated in Figure 3.3 below. Results from the Yoyo II test were recorded by Ajax Cape Town FC coaching staff and sent to the researcher via email. The results were downloaded by the researcher and kept on a personal, access controlled laptop for the duration of the study. The test is part of regular testing at the club and no familiarisation with the test was needed. The purpose of the YoyoII test was to provide the researcher with a maximal test to compare hormone response to exercise in SSGs and matchplay.

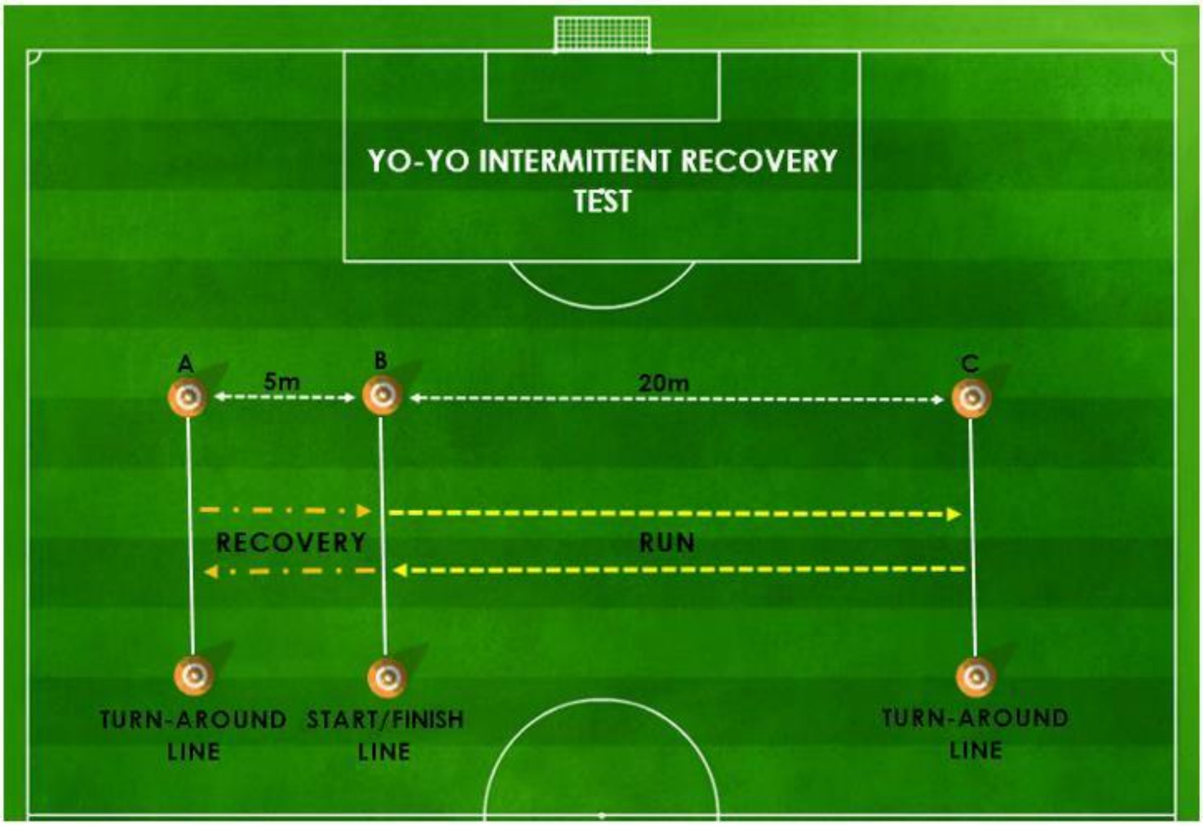

Figure 3-3 Visual representation of the Yoyo Level Two Intermittent Endurance Test. Adapted from Science for Sport (2016)

The Yoyo II is a field test that was developed to try and better mirror the environment of a soccer match compared to traditional, continuous endurance tests (Bradley *et al.*, 2011). The Yoyo test has the advantage of all field-based tests in that all players are able to perform the test at the same time which allows for frequent, easy and cheap testing (Bradley *et al.*, 2011). The Yoyo Intermittent Endurance Test level II is defined by Bradley *et al.* (2011, p. 971) as, "lasting 6-25min and consists of repeated 20-m shuttle runs at progressively increasing speeds dictated by an audio bleep emitted from a CD player". The Yoyo test that was used in this study was performed in exactly the same fashion as the Yoyo test described by Bradley *et al.* (2011, p. 971) who state that, "Between each shuttle the players had a 5-s period of jogging around a marker placed 2.5 m behind the finishing line. Failure to achieve the shuttle run in time on two occasions resulted in termination of the test". Upon termination of the test, the final distance is written down and recorded for each player. The Yoyo II was reported by Bradley *et al.* (2011) as having an intra and inter-season test-retest coefficient of variance of 4.2 – 5.6% and that there is a correlation ($P < 0.05$) between yoyo II performance ($r = 0.74$) and high-intensity running distance in a soccer match ($r = 0.58$). Bradley *et al.* (2011) also reported a correlation ($P < 0.01$) between yoyo II heart rate and the peak values for high-intensity running in midfielders in 5 – 15min periods ($r = -0.71$ and -0.77).

Training Characteristics

Warm-up

All training sessions began with a football specific warm up that is relatively standard. Ajax Cape Town has developed several different warm-ups that incorporate slow to medium pace jogging, dynamic stretching and ball/skill work. The warm-up usually lasted for ± 15min beginning with several straight line jogs. Straight line jogging included not only normal jogging, but rhythmic-based movements such as: knee raises, kicking butts, side-shuffling, skipping, hip circles and several other styles of movement. After jogging the players progressed into dynamic stretching which included several types of stretches aimed at warming up all of the muscles that may be required in a normal soccer training session. Such stretches included: several types of leg swings, squats, lunges, dynamic hamstring and quadriceps exercises, shoulder circles and neck stretches and various posterior chain stretches. Lastly, players progressed into ball specific warm-up. The ball specific warm-up is aimed at preparing the players for soccer specific actions that may follow in the normal training session through repeated stimulus at a slightly lower intensity level than is expected during the training session to follow. Usually this comprised of half the squad jogging in arbitrary directions (open environment) with the ball while the other half of the squad stands still without the ball. Players with the ball are required to perform several soccer specific actions including: basic passing, one touch passing, leading, controlling of the ball in the air/on the ground, heading of the ball etc. The players without the ball then swap with the players with the ball and this process is repeated.

Soccer-conditioning sprints

Upon completion of the warm-up, the players would perform soccer conditioning sprints. These sprints required players to race one another in a straight line in a one-on-one situation. These sprints were structured in a soccer-specific manner as the players are not only racing one another, but chasing after a ball in an attempt to score a goal against a goalkeeper, that stood 30-40m away in goalposts. Generally, a situation arose where to players would sprint towards a ball that had been passed by a coach to about 20m away from the start line, the player who got to the ball first would try to score immediately while the other player would try to block the shot; players would then return to the start line and repeat the exercise. The soccer- conditioning sprints would usually comprise of two sets of six to eight 20m sprints with 30 seconds rest between sprints and a 4min rest between sets.

Small-sided-game

Following the warm-up and soccer-conditioning sprints, the planned SSG for the session would begin. SSGs were group as small, medium, and large SSGs that aimed at improving the cardiovascular fitness levels of the players as the season progressed. The Ajax Cape Town coaches would plan a periodised program for the year, altering training volume and intensity for different outcomes, and they would try to stick as accurately as possible to that program detailed in Table 3.2 below.

Table 3-2 Description of Small-sided-game parameters which Ajax Cape Town coaches alter in order to achieve varying training outcomes.

	Ajax Cape Town FC SSG Approach to Cardiovascular Fitness		
Size	Small	Medium	Large
No. Players	3 – 5 players	6 – 8 players	9 – 11 players
Pitch Dimensions	20 – 40m x 12 – 24m	50 – 70m x 30 – 42m	80 – 100m x 48 – 60m
No. Repetition	5 – 8	3 – 5	1 – 3
Repetition length	1 – 4 min	5 – 10min	10 – 20min
No. Sets	1 – 4	1 – 3	1 - 2
Rest Between Reps	1 – 2min	2 – 4min	4 – 6min
Rest Between Sets	4 – 6min	2 – 3min	1 – 2min

Ajax Cape Town coaches prefer to use six week macrocycles structured in one of two ways in order to periodise the training year (mentioned above). Either a one-by-six-week cycle or a two-by-three-week cycle is used when planning the years‟ conditioning as depicted in Table 3.3 below.

Table 3-3 Representation of Ajax Cape Town's six week macrocycles when periodising the training year structured either in a 1x6 or 2x3 week manner.

Macrocycle	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Microcycle (1x6 week)	4v4	4v4	7v7	7v7	11v11	11v11
Microcycle (2x3 week)	4v4	7v7	11v11	4v4	7v7	11v11

In all SSG training sessions in which saliva samples were collected for this study, the parameters (which fall within the normal range provided in Table 3.2.) in Table 3.4. below were used.

Table 3-4 The SSG characteristics during which saliva samples were collected.

No. Players	4v4	7v7	11v11
Field Size (metres)	40 x 30	70 x 34	100 x 60
Date	11/11/2014	03/09/2014	29/08/2014
No. Reps	6	3	2
Duration of Reps (minutes)	1.5	6.67	12
Rest Between Reps (minutes)	2	2	5
No. Sets	2	1	1
Rest Between Sets (minutes)	4	N/A	N/A

Statistical Analysis

Given the fact that the distribution of the data in the study was not normal, all measurements were log transformed to normalise the data set. The level of significance was set at 95% ($P \leq 0.05$). A mixed model repeated measures ANOVA with position and time as fixed effects and the players as mixed effect was used to analyse the data. For post hoc testing, Fisher's least significant difference (LSD) testing was used.

Lastly, Cohen's d test for effect sizes was used to determine practical significance. However, upon the instruction of the university's statistical expert it was recommended that for the interaction terms, the sample sizes were small and in some cases the effect size could not be calculated. Additionally, the statistical expert suggested that other effect sizes may be misleading due to small sample sizes. It was therefore decided by the researcher to leave the effect sizes out of the Results Chapter but they have been included in Appendix D for the benefit of the reader.

Chapter Four

Results

Introduction

Over the duration of the study, 22 different players provided saliva samples at any given point. Players were then divided into playing position with four different goalkeepers, seven defenders, six midfielders, and five attackers taking part over the duration of the study. Of those players, only 14 completed post-season saliva sampling. 18 players provided pre-season saliva samples, 15 players were tested after the YoyoII test, 10 were tested during the competitive match and 11v11 SSG, 11 were tested during the 7v7 SSG, 9 in the 4v4 SSG, and 8 in the friendly match. The reason for the inconsistency of testing was due to the nature of the season with certain players dropping out of the club or team, certain players falsifying their samples and lab errors. The dynamic environment of testing has been listed as a limitation of the study later on in text.

One of the participants produced a testosterone concentration of 103,73 times higher than the mean concentration of the team during the pre-season baseline measurement (here forth named case 33). After log transforming all data sets and performing a test for outliers, case 33 was excluded from the statistical analysis. Another participant produced a testosterone concentration 36,51 times higher than the mean team testosterone concentration during the 7v7 SSG measurement (here forth named case 26). Owing to the fact that this measurement was a concentration in response to an acute bout of exercise as opposed to a resting level measurement, as in the case of case 33, case 26 was originally included in statistical analysis. However, owing to a relatively small sample size, the data point skewed the data to a large degree and thus case 26 was both included and excluded in the data analysis. It is important to note that case 26 was originally included in the data set because it did not fall outside of the normative range after log transforming the original data set and running an outliers test. Therefore, a total of 22 players were used for final statistical analysis and at first 94 data points were analysed (excluding case 33) and, secondly, 93 data points (cases) were analysed (excluding cases 33 and 26).

DHEA will only be briefly reported on in this chapter owing to the fact that there were no statistically significant differences between playing positions or over any time points for the entire team ($P > 0.05$). The DHEA response of the team after exercise presented with very little change, and rather than leave out the results, they have been stated later on in this chapter and hypotheses for the lack of change in DHEA response to exercise will be provided in Chapter Five.

Letters on all the figures below indicate statistical significance, where any two points that do not share a common letter are statistically significantly different to one another ($P < 0.05$). This method of indicating statistical significance will be used throughout Chapter Four.

Acute Endocrine Response to Training (including case 26)

No statistically significant differences in cortisol, testosterone and T:C ratio concentration was found between the playing positions of GK, DEF, MID, and ATT over the three different types of SSGs. This finding made further investigation into positional differences in response to SSG training stimuli redundant. Rather, the squad was investigated as a whole unit to determine whether there were any changes in response to training within the entire team.

Table 4-1 The mean (± SD) cortisol concentration (ng/ml) between the various playing positions across all training sessions (11v11, 7v7, and 4v4).

	Playing Positions			
Session	GK	DEF	MID	ATT
Baseline Pre Season	0,39 ± 0,12	2,30 ± 3,55	0,61 ± 0,49	0,43 ± 0,17
11v11	0,36 ± 0	0,30 ± 0,14	1,17 ± 0,25	0,70 ± 0,24
7v7	0,76 ± 0	0,92 ± 0,53	3,77 ± 0	2,67 ± 2,40
4v4	0,47 ± 0	1,55 ± 0,88	1,51 ± 0,37	0,96 ± 0,62

$P > 0.05$

Table 4-2 The mean (± SD) testosterone concentration (ng/ml) between the various playing positions across all training sessions (11v11, 7v7, and 4v4).

	Playing Position			
Session	GK	DEF	MID	ATT
Baseline Pre Season	0,08 ± 0,01	0,18 ± 0,15	0,09 ± 0,01	0,42 ± 0,68
11v11	0,21 ± 0	0,14 ± 0,02	0,13 ± 0,09	0,15 ± 0,26
7v7	0,25 ± 0	0,33 ± 0,28	0,22 ± 0	2,40 ± 3,92
4v4	0,12 ± 0	0,16 ± 0,63	0,12 ± 0,03	0,14 ± 0,06

$P > 0.05$

Table 4-3 The mean (± SD) T:C Ratio (ng/ml) between the various playing positions across all training sessions (11v11, 7v7, and 4v4).

	Playing Position			
Session	GK	DEF	MID	ATT
Baseline Pre Season	0,23 ± 0,50	0,18 ± 0,13	0,26 ± 0,16	1,52 ± 2,71
11v11	0,58 ± 0	0,59 ± 0,22	0,13 ± 0,11	0,26 ± 0,14
7v7	0,33 ± 0	0,54 ± 0,33	0,06 ± 0	2,76 ± 2,79
4v4	0,26 ± 0	0,18 ± 0,15	0,09 ± 0,04	0,25 ± 0,20

$P > 0.05$

No statistically significant differences in cortisol, and T:C ratio concentration were found amongst the team when comparing baseline (resting) hormone concentrations to acute, or post SSG hormone concentration after data points were normalised. However, as illustrated in Table 4.4 and Figure 4.1 below, there was a statistically significant change in testosterone concentration of the entire team after a 7v7 SSG when compared to baseline (resting) concentration levels. Upon further investigation, it was found that this statistically significant difference was not supported by the non- significant F-test p-value and therefore this difference can only be recorded as a trend. The other two SSGs did not produce a statistically significant change in testosterone concentration when compared to baseline.

Table 4-4 The endocrine responses of the total group to all training sessions (11v11, 7v7, and 4v4).

		Session		
Hormone	Baseline Pre Season	11v11	7v7	4v4
Cortisol	1,03 ± 2,11	0,68 ± 0,41	1,80 ± 1,82	1,23 ± 0,75
Testosterone	0,21 ± 0,40	0,15 ± 0,06	1,06 ± 2,58 *	0,14 ± 0,06
T:C Ratio	0,60 ± 1,59	0,35 ± 0,25	1,30 ± 2,05	0,19 ± 0,16

Statistically significant difference between testosterone concentration (ng/ml) after the 7v7 training session compared to baseline pre-season. (*$P < 0.05$).

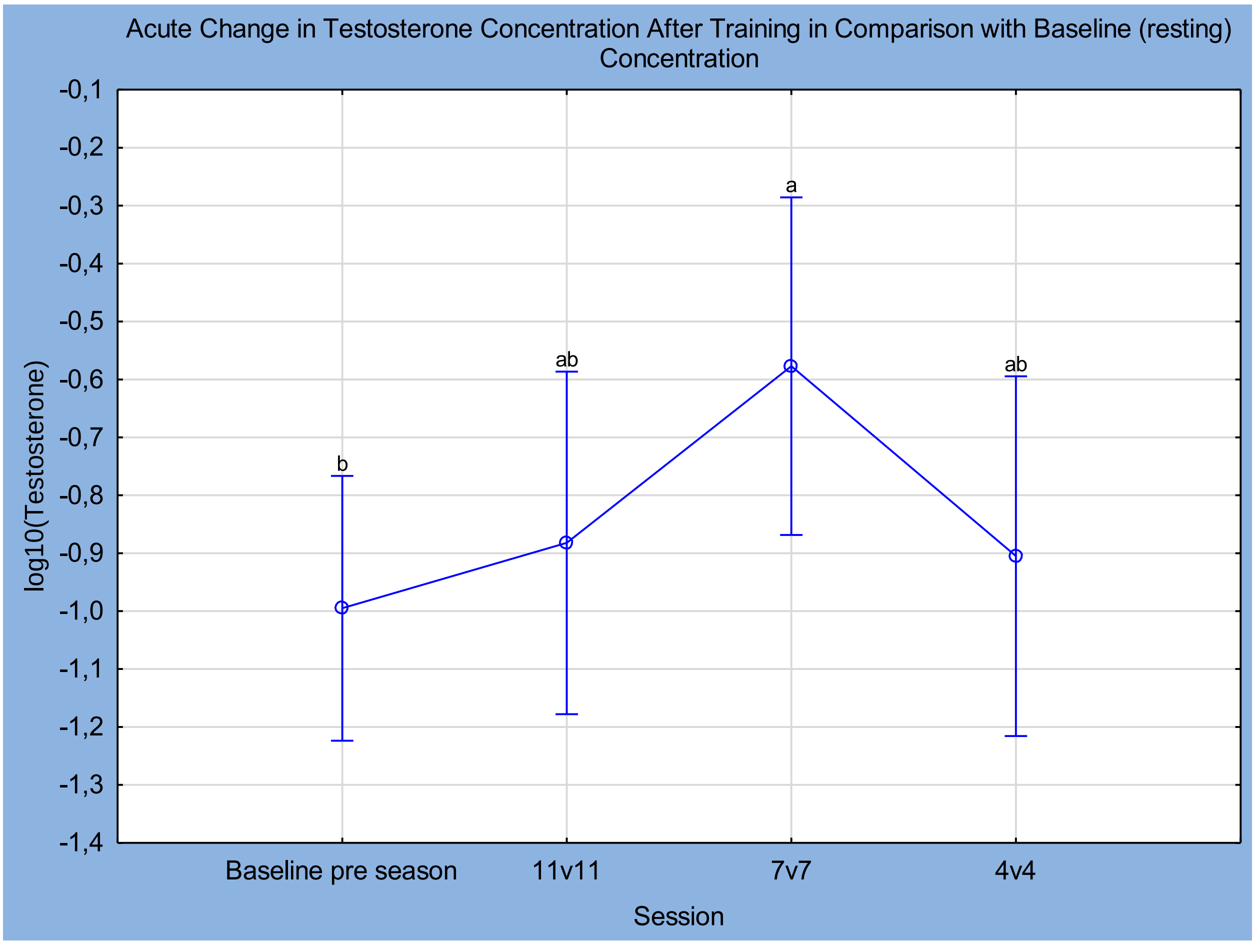

Figure 4-1 The acute change in testosterone concentration in response to all training stimuli amongst the entire team. Statistically significant difference between testosterone concentration (ng/ml) after the 7v7 training session compared to baseline pre-season. (P = 0.02).

Acute Endocrine Response to Training (excluding case 26)

As mentioned in the introductory paragraph, case 26 was a reading provided by one of the players in the 7v7 SSG that was markedly higher (36.51 times) than the mean testosterone concentration of the team. After applying an outliers test to the data, it was decided to keep case 26 in the analysis as it fell within normal ranges. However, the fact that the sample size is relatively small for the study in general – and the 7v7 SSG specifically – there is a worry that case 26 may skew the data, providing a possible explanation for the statistically significant change in testosterone concentration when comparing baseline (resting) concentration to the 7v7 SSG.

The exclusion of case 26 did not alter the positional data when comparing position and all sessions in a two way ANOVA. As in Figure 4.2 below, no statistically significant differences were found in testosterone concentration between playing positions amongst all time points, as is the case with the T:C ratio which has not been illustrated.

Once again, the squad was investigated as a whole unit to determine whether there were any changes in response to training when case 26 was left out of the data set.

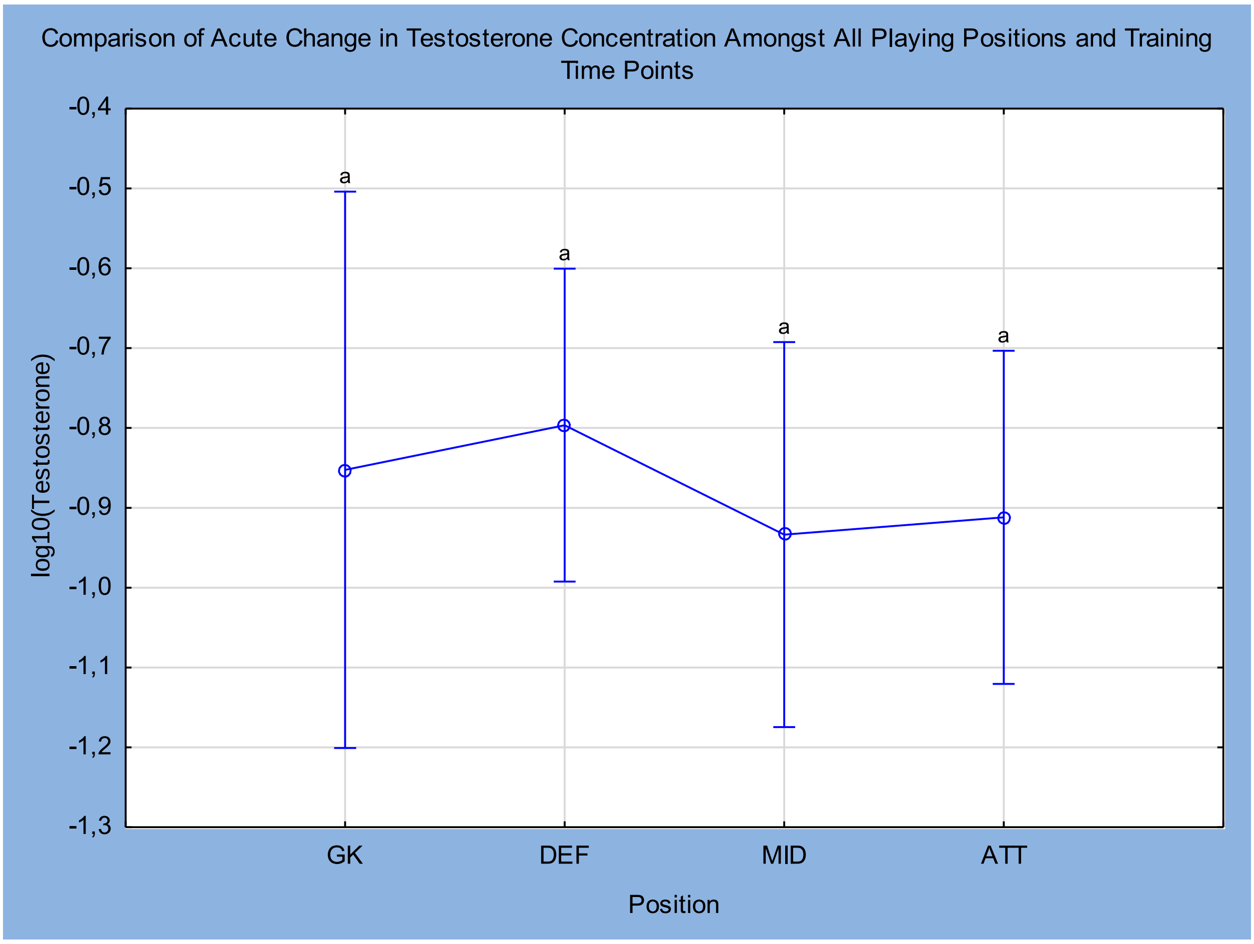

Figure 4-2 The influence of excluding case 26 from the analysis on playing position and testosterone concentrations. (P > 0.05).

Table 4-5 Illustration of the influence of excluding case 26 from the analysis on the squad's; cortisol, testosterone and T:C ratio. Notice a marked change in the squad's mean 7v7 [testosterone] compared to Table 4.4 above.

	Session			
Hormone	Baseline Pre Season	11v11	7v7	4v4
Cortisol	1,03 ± 2,11	0,68 ± 0,41	1,78 ± 17	1,23 ± 0,75
Testosterone	0,21 ± 0,40	0,15 ± 0,06	0,25 ± 0,22	0,14 ± 0,06
T:C Ratio	0,60 ± 1,59	0,35 ± 0,25	0,98 ± 1,88	0,19 ± 0,16

P > 0.05

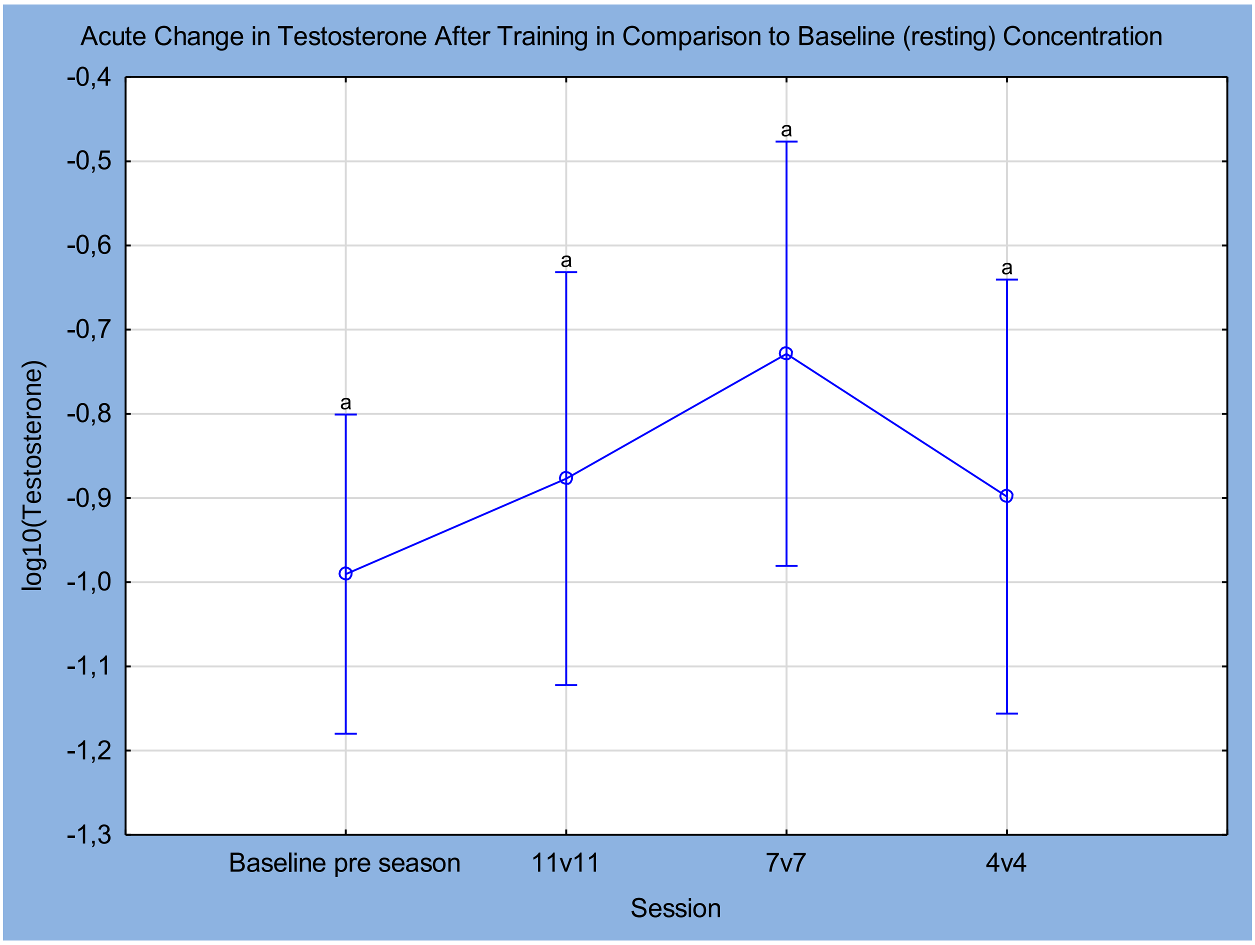

Figure 4-3 The influence of excluding case 26 from the analysis of the team's baseline (resting) testosterone in comparison to the acute response to the 7v7 SSG.

The influence of excluding case 26 from the data set resulted in there no longer being a statistically significant difference between the team's mean baseline (resting) testosterone concentration and the mean testosterone concentration immediately after the 7v7 SSG (P = 0.09).

Acute Endocrine Response to Match-play and Maximal Testing

Baseline saliva samples were collected at approximately 3-4pm whereby players used a straw to fill up a test tube with saliva. Players had not trained the previous day and were at rest upon providing saliva samples. Players were asked not to eat or drink anything immediately prior to providing their respective samples. The same procedure was followed for the samples provided immediately after FRIE, COMP, and YOYO whereby players provided their sample within 30min after completion of exercise.

No statistically significant differences were found between playing positions and the endocrine response to match play and maximal exercise testing. After normalising the data and performing a two way ANOVA, each playing position presented similar changes in endocrine response to one another during match play and maximal testing. Therefore, it was unnecessary to do further data analysis on individual playing positions, but rather focus on the endocrine response of the team as a whole. Additionally, the goalkeeper score for the friendly match was not available as the goalkeeper was substituted in the match and then returned to the field later on due to an injury picked up in the first half.

Table 4-6 The mean (± SD) cortisol concentration (ng/ml) between the various playing positions across all match / performance testing sessions.

			Position	
Session	GK	DEF	MID	ATT
Baseline Pre Season	0,39 ± 0,12	2,30 ± 3,55	0,61 ± 0,49	0,43 ± 0,17
Baseline End Season	1,10 ± 0	0,61 ± 0,29	0,53 ± 0,35	0,89 ± 0,47
Yoyo II	0,34 ± 0	0,52 ± 0,14	0,58 ± 0,35	0,95 ± 0,56
Competitive	0,18 ± 0	3,63 ± 0,81	3,94 ± 2,80	6,28 ± 4,88
Friendly	N/A	1,06 ± 0	1,59 ± 1,58	1,51 ± 0,42

$P > 0.05$

Table 4-7 The mean (± SD) testosterone concentration (ng/ml) between the various playing positions across all match / performance testing sessions.

	Position			
Session	GK	DEF	MID	ATT
Baseline Pre Season	0,08 ± 0,01	0,18 ± 0,15	0,09 ± 0,01	0,42 ± 0,68
Baseline End Season	0,19 ± 0	0,21 ± 0,04	0,45 ± 0,51	0,19 ± 0,06
Yoyo II	0,28 ± 0	0,25 ± 0,13	0,30 ± 0,05	0,29 ± 0,04
Competitive	0,18 ± 0	0,54 ± 0,43	0,20 ± 0,61	0,30 ± 0,10
Friendly	N/A	0,07 ± 0	0,14 ± 0,07	0,11 ± 0,04

$P > 0.05$

Table 4-8 The mean (± SD) [T:C Ratio ng/ml] between the various playing positions across all match / performance testing sessions.

	Position			
Session	GK	DEF	MID	ATT
Baseline Pre Season	0,23 ± 0,50	0,18 ± 0,13	0,26 ± 0,16	1,52 ± 2,71
Baseline End Season	0,17 ± 0	0,50 ± 0,34	2,17 ± 3,24	0,28 ± 0,17
Yoyo II	0,82 ± 0	0,51 ± 0,48	0,71 ± 0,32	0,47 ± 0,31
Competitive	1,01 ± 0	0,13 ± 0,08	0,09 ± 0,06	0,09 ± 0,05
Friendly	N/A	0,06 ± 0	0,33 ± 0,33	0,83 ± 0,47

$P > 0.05$

A statistically significantly higher concentration of cortisol amongst the team in response to competitive match play is shown in Figure 4.4 and Table 4.9 below. When comparing COMP to END ($p = 0.001$), COMP to YOYO ($p = 0.001$) and COMP to FRIE ($p = 0.02$) there is clearly a statistically significant increase in cortisol concentration amongst the whole team when competing in a competitive match, not only to resting cortisol concentrations, but to other types of exercise too. Notably, when comparing FRIE to PRE ($p = 0.05$) and FRIE to YOYO ($p = 0.06$), the increase in cortisol concentration immediately after FRIE falls narrowly outside of the 95% confidence limits.

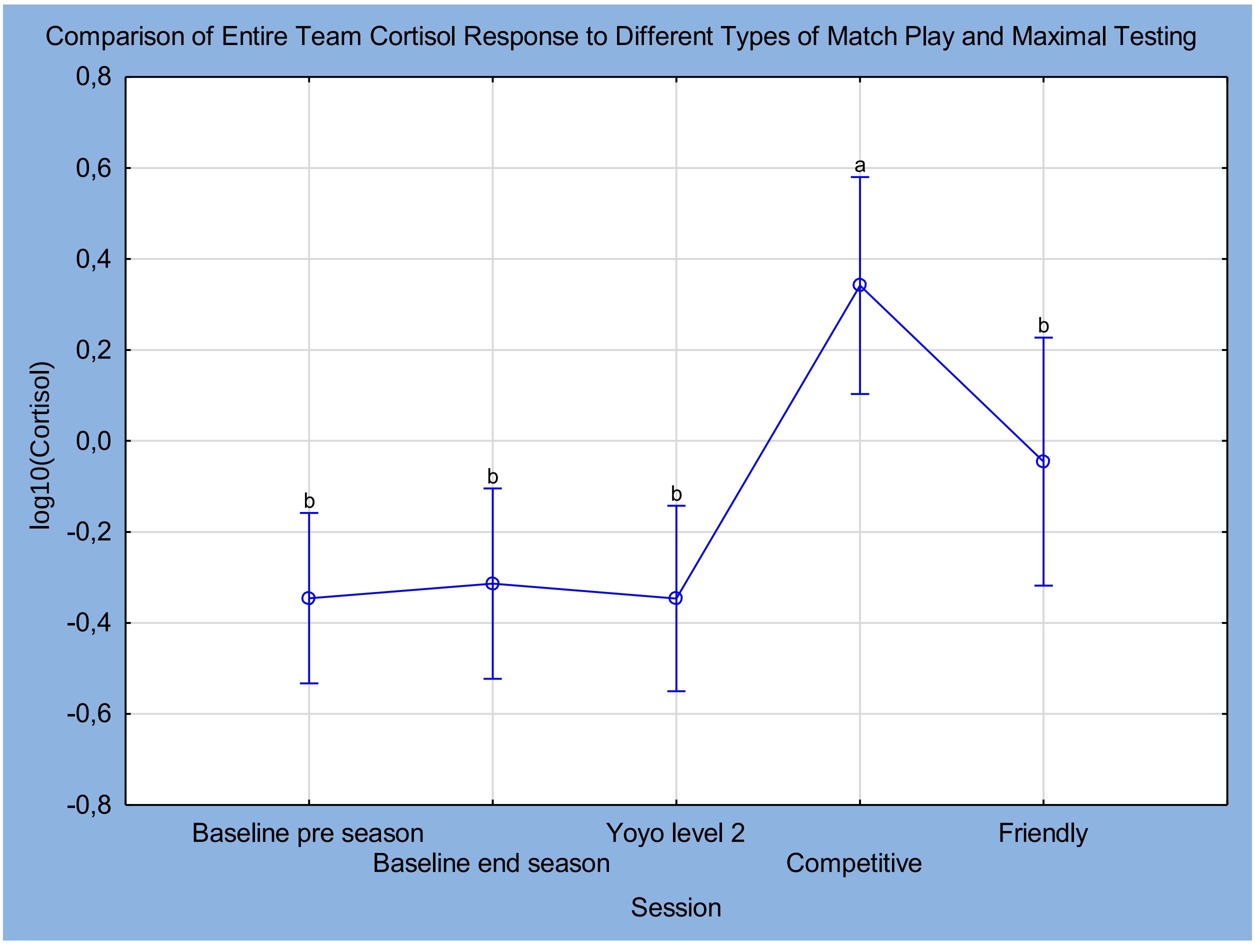

Figure 4-4 **Chronic resting and acute cortisol concentration response to match play and performance testing. Statistically significant difference between cortisol concentration (ng/ml) in competitive and friendly matches (P < 0.05). Statistically significant difference between cortisol concentration (ng/ml) at rest and after competitive match-play (P < 0.01).**

Table 4.9 and Figure 4.5 below shows the statistically significant differences - using the entire team's data - in testosterone concentration between PRE and END (p = 0.02), PRE and YOYO (p = 0.01), PRE and COMP (p = 0.01) as well as statistically significant differences in YOYO and FRIE (p = 0.03) and COMP and FRIE (p = 0.03). Notably, the team presented with statistically significantly higher resting testosterone concentrations toward the end of the season when compared to the beginning of the season, while the competitive match produced a statistically significantly greater response in testosterone secretion when compared to baseline than the friendly match did.

Table 4-9 The endocrine response of the total group to match-play / performance testing in comparison with baseline (resting) endocrine concentrations as well as baseline end season compared to baseline pre- season.

	Session				
Hormone	Baseline Pre Season	Baseline End Season	Yoyo II	Competitive	Friendly
Cortisol	1,029 ± 2,114	0,701 ± 0,401	0,666 ± 0,408	3,938 ± 3,259 **	1,492 ± 1,157
Testosterone	0,212 ± 0,403	0,270 ± 0,298 *	0,274 ± 0,091	0,322 ± 0,285	0,119 ± 0,062
T:C Ratio	0,603 ± 1,590	0,891 ± 1,929	0,572 ± 0,396	0,193 ± 0,280 **	0,203 ± 0,267 **

Statistically significant difference between testosterone concentration at post-season baseline compared to pre-season baseline (*P < 0.05). Statistically significant difference between cortisol concentration after competitive match compared to baseline and T:C ratio of both competitive and friendly matches in comparison to baseline (** P < 0.01).

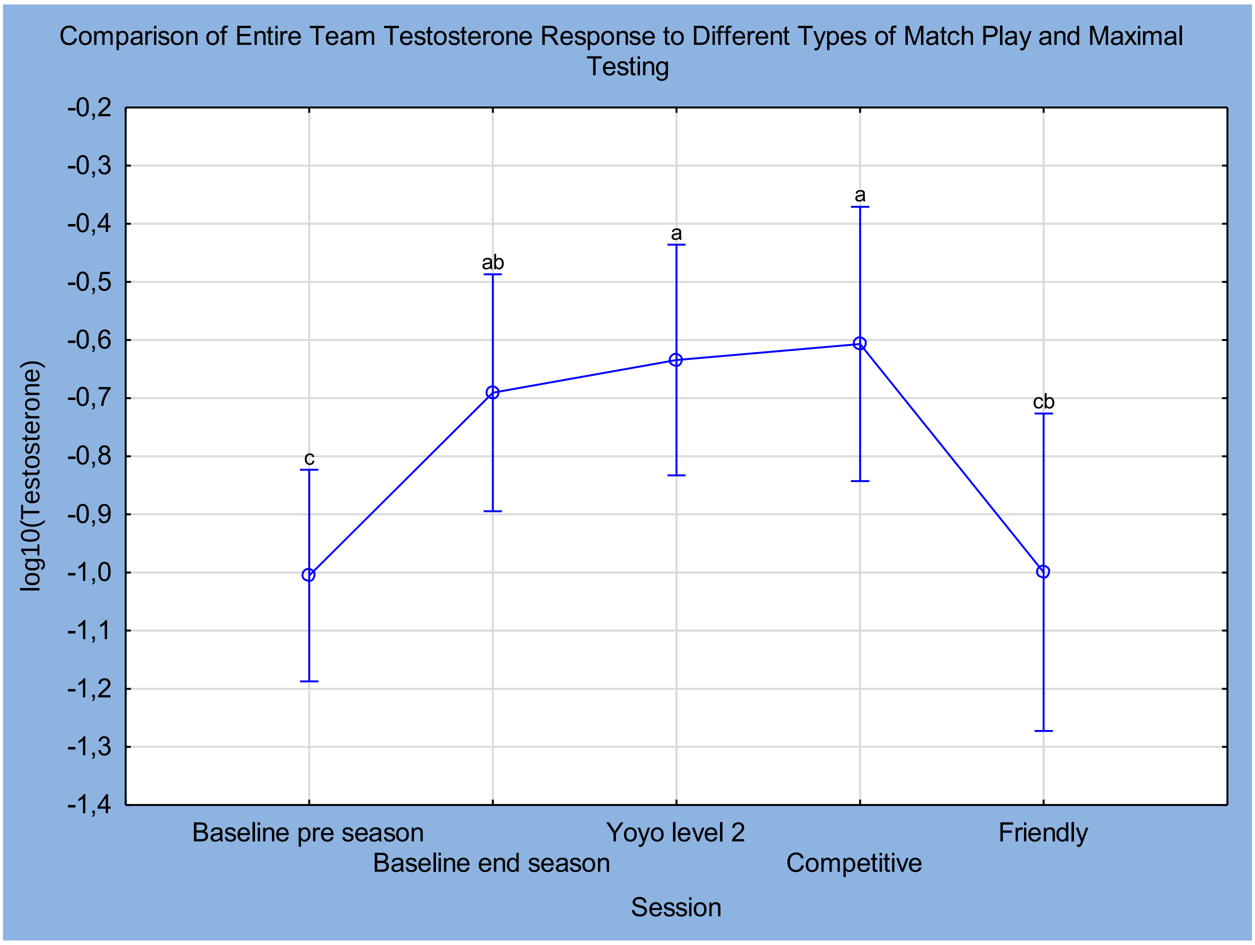

Figure 4-5 Chronic resting and acute testosterone concentration response to match play and maximal testing. Statistically significant difference between testosterone concentration (ng/ml) of the group as a whole between; baseline at pre-season and end of season, YoyoII and friendly match-play and competitive and friendly match-play (P < 0.05). Statistically significant difference between baseline pre-season and yoyo II, baseline pre-season and competitive match- play (P < 0.01).

Figure 4.6 and Table 4.9 illustrate the statistically significant T:C ratio differences of the team's mean T:C ratio between PRE and YOYO (P = 0.04), END and COMP (P = 0.01), END and FRIE (P = 0.01), YOYO and COMP (P = 0.01) and YOYO and FRIE (P = 0.01). Notably, there was a marked decrease in T:C ratio compared to resting levels after both the FRIE and COMP matches and interestingly there was no such trend for the YOYO maximal exercise test. There was no statistically significant difference between PRE and END, however, there was a slightly higher mean resting T:C ratio amongst the team and the END testing period.

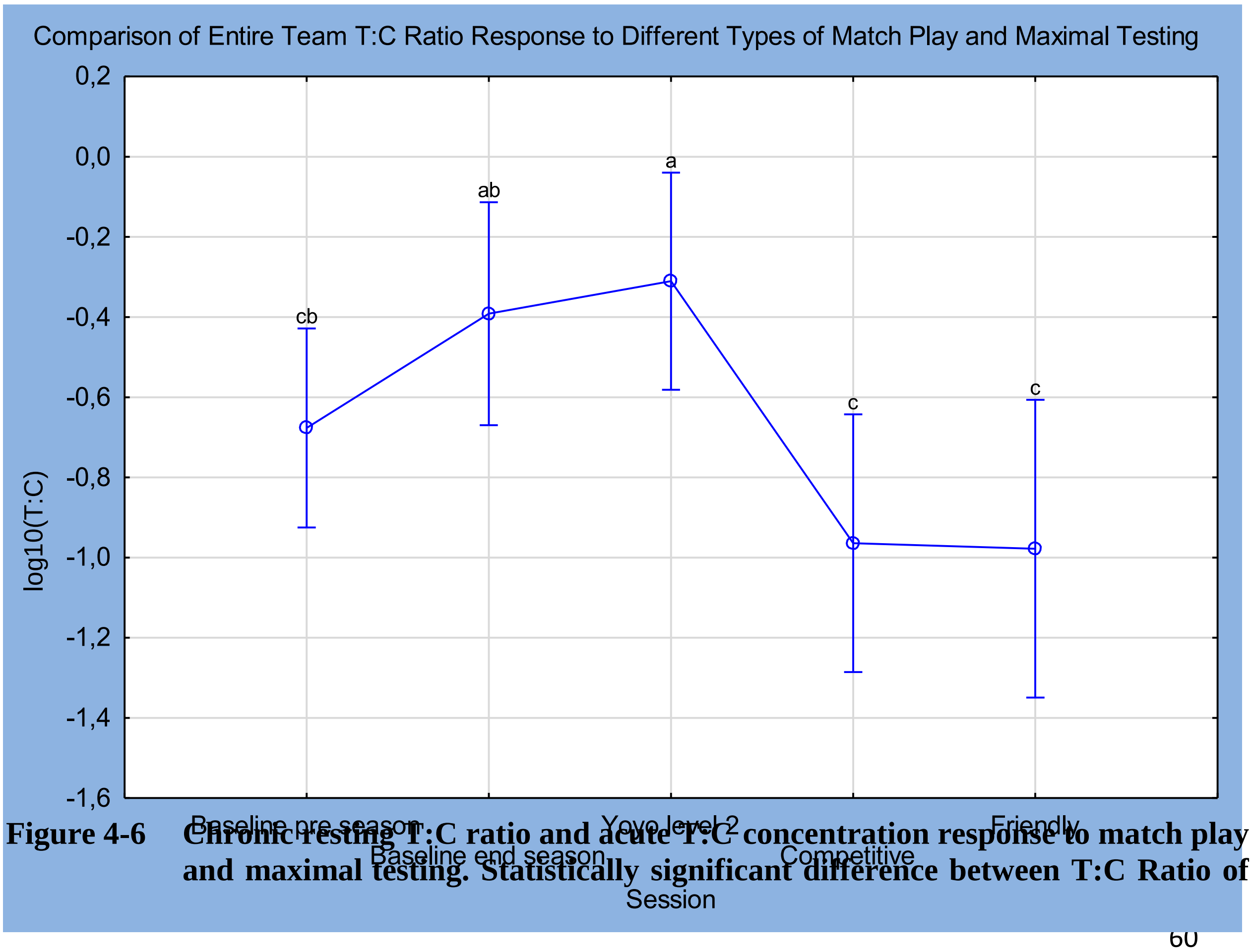

Figure 4-6 Chronic resting T:C ratio and acute T:C concentration response to match play and maximal testing. Statistically significant difference between T:C Ratio of

the group as a whole of in baseline pre-season and yoyo II (P < 0.05). Statistically significant difference between baseline end of season and friendly match-play, yoyo II and competitive match-play, and yoyo II and friendly match-play (P < 0.01).

Comparing Acute Endocrine Response Between Match-play and Training

The specific aims of the study require SSGs to be compared to match-play and maximal testing in order to determine whether training conditioning mirrors the physical demands of match-play. While no statistically significant differences were found amongst playing position when comparing SSGs to match-play and maximal exercise testing, there were several differences when comparing the SSGs to match-play and maximal exercise testing of the entire team.

Table 4-10 Raw, mean, concentrations (ng/ml) for all endocrine markers (excluding DHEA) for the group as a whole over all training, match and baseline periods.

	Hormone		
Session	Cortisol	Testosterone	T:C Ratio
Baseline Pre Season	1,03 ± 2,11	0,21 ± 0,40	0,60 ± 1,59
11v11	0,68 ± 0,41	0,15 ± 0,06	0,35 ± 0,25
7v7	1,80 ± 1,82	1,06 ± 2,58	1,30 ± 2,05
4v4	1,23 ± 0,75	0,14 ± 0,06	0,19 ± 0,16
Baseline End Season	0,70 ± 0,40	0,27 ± 0,30	0,89 ± 1,93
Yoyo II	0,67 ± 0,41	0,27 ± 0,09	0,57 ± 0,40
Competitive	3,94 ± 3,26	0,32 ± 0,29	0,19 ± 0,28
Friendly	1,49 ± 1,16	0,12 ± 0,06	0,20 ± 0,27

Raw values (ng/ml) of the total group at all time points represented through means and standard deviations.

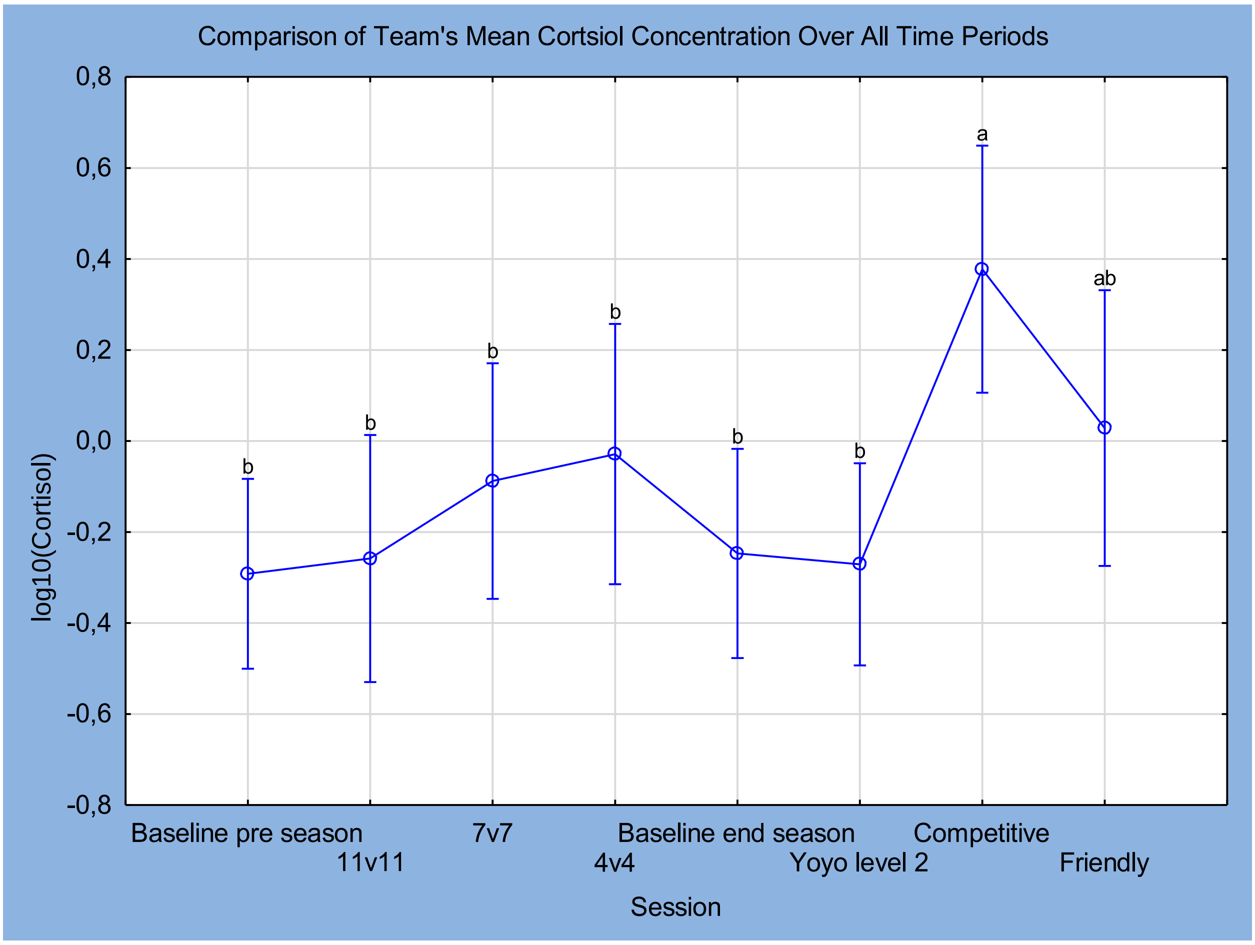

Figure 4-7 **The mean cortisol concentration of the team over all the time points with special reference to SSGs in comparison to matches and maximal testing. Statistically significant difference (P < 0.05) between competitive match and 4v4 cortisol response. Statistically significant difference (P < 0.01) between competitive match and baseline pre-season, 11v11, 7v7, baseline end season and YoyoII**

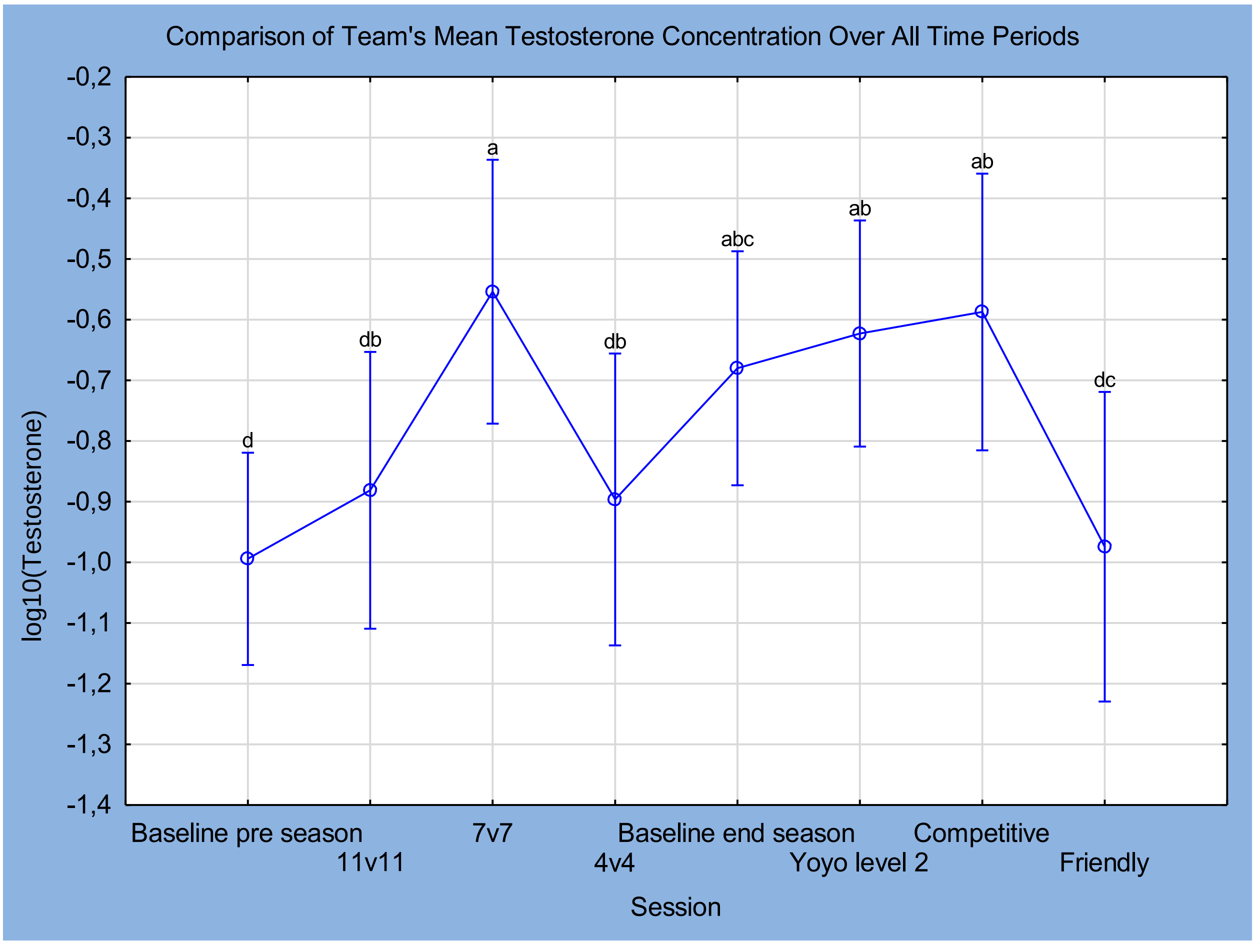

Figure 4-8 **The team's mean testosterone concentration over all time points with special reference to SSGs in comparison to matches and maximal testing. Statistically significant difference between 7v7 and 11v11, 4v4 and 7v7, friendly and YoyoII, post-season baseline and pre-season baseline, and friendly and competitive match testosterone response ($P < 0.05$). Statistically significant difference between 7v7 and pre-season baseline, YoyoII and pre-season baseline, competitive match and baseline pre-season, and friendly and 7v7 ($P < 0.01$).**

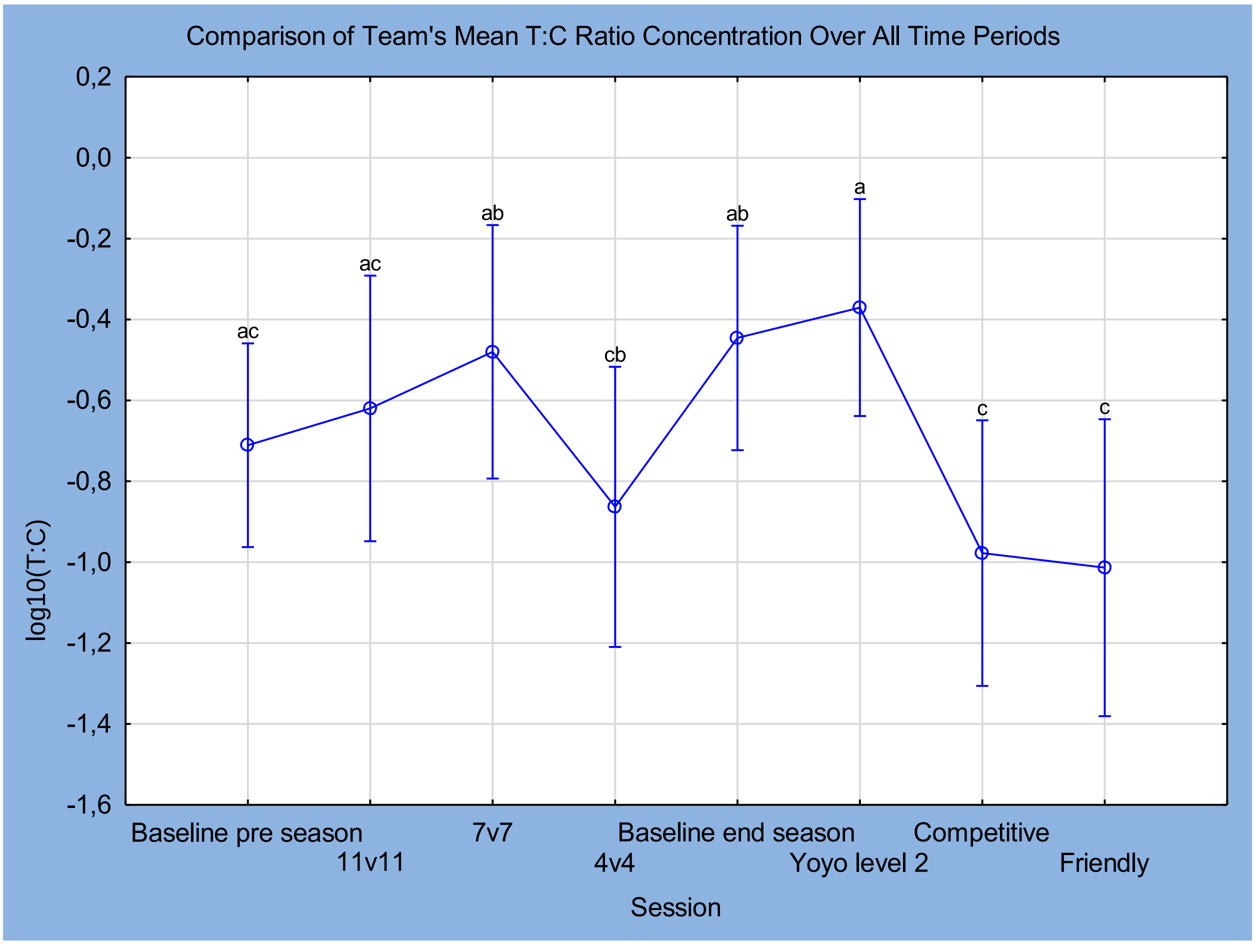

Figure 4-9 The team's mean acute T:C ratio over all time points with special reference to SSGs in comparison to matches and maximal testing. Statistically significant difference between competitive match and 7v7, friendly and 7v7, YoyoII and 4v4, competitive and baseline end season, and friendly and baseline end season T:C ratio ($P < 0.05$). Statistically significant difference between competitive match and yoyo2 and friendly and YoyoII ($P < 0.01$).

It is clear through the observation of Figures 4.7, 4.8, and 4.9 and Table 4.10 above that there are several statistically significant differences in cortisol, testosterone and T:C concentrations when comparing the entire team as opposed to within their positional constraints. No statistically significant differences were found between playing positions and between the team as a whole with the DHEA concentrations illustrated below.

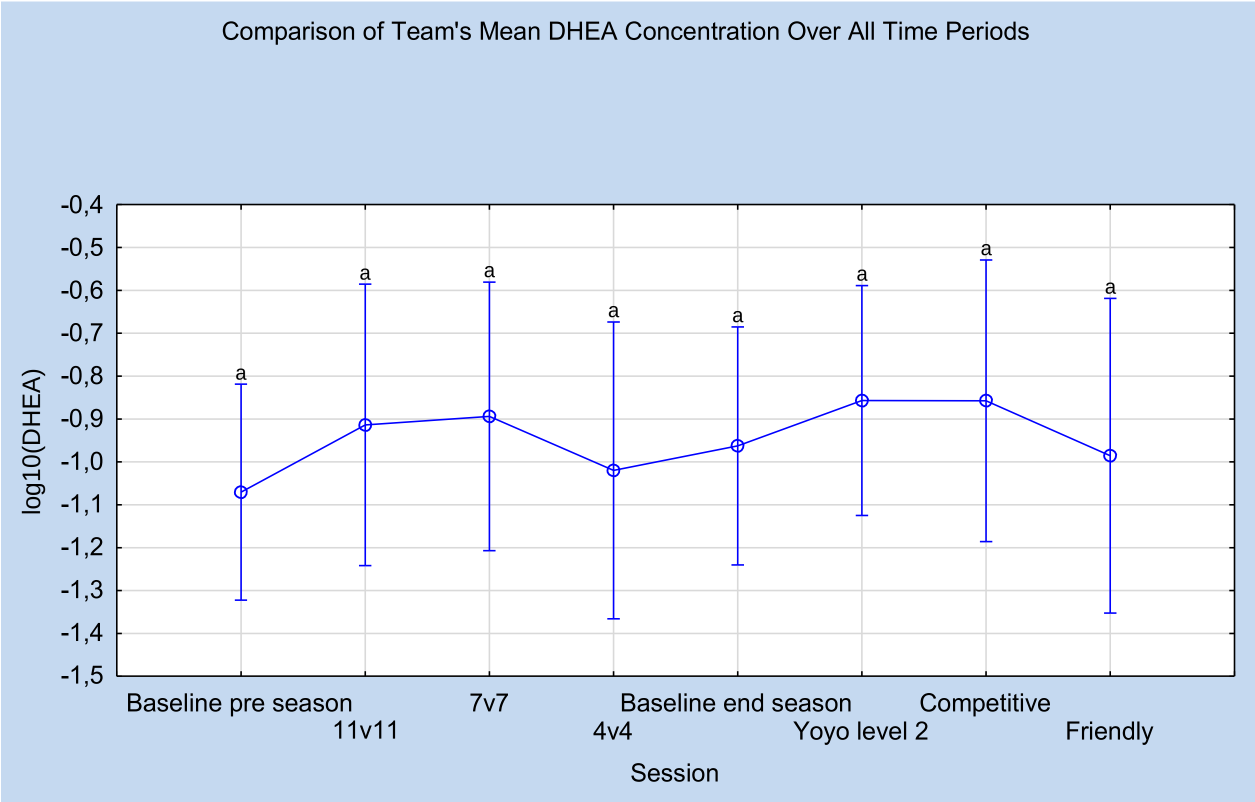

Figure 4-10 The acute DHEA concentration of the team over all of the time points. P > 0.05.

Yoyo Level II Intermittent Endurance Test Results

When comparing YoyoII performance amongst playing positions, there was a statistically significant difference between distances covered by the goalkeepers and distances covered by the other three playing positions. Goalkeepers covered statistically significantly less distance in this performance test when compared to the other groups ($p < 0.05$), while the other positions compared against one another produced extremely similar total distance covered.

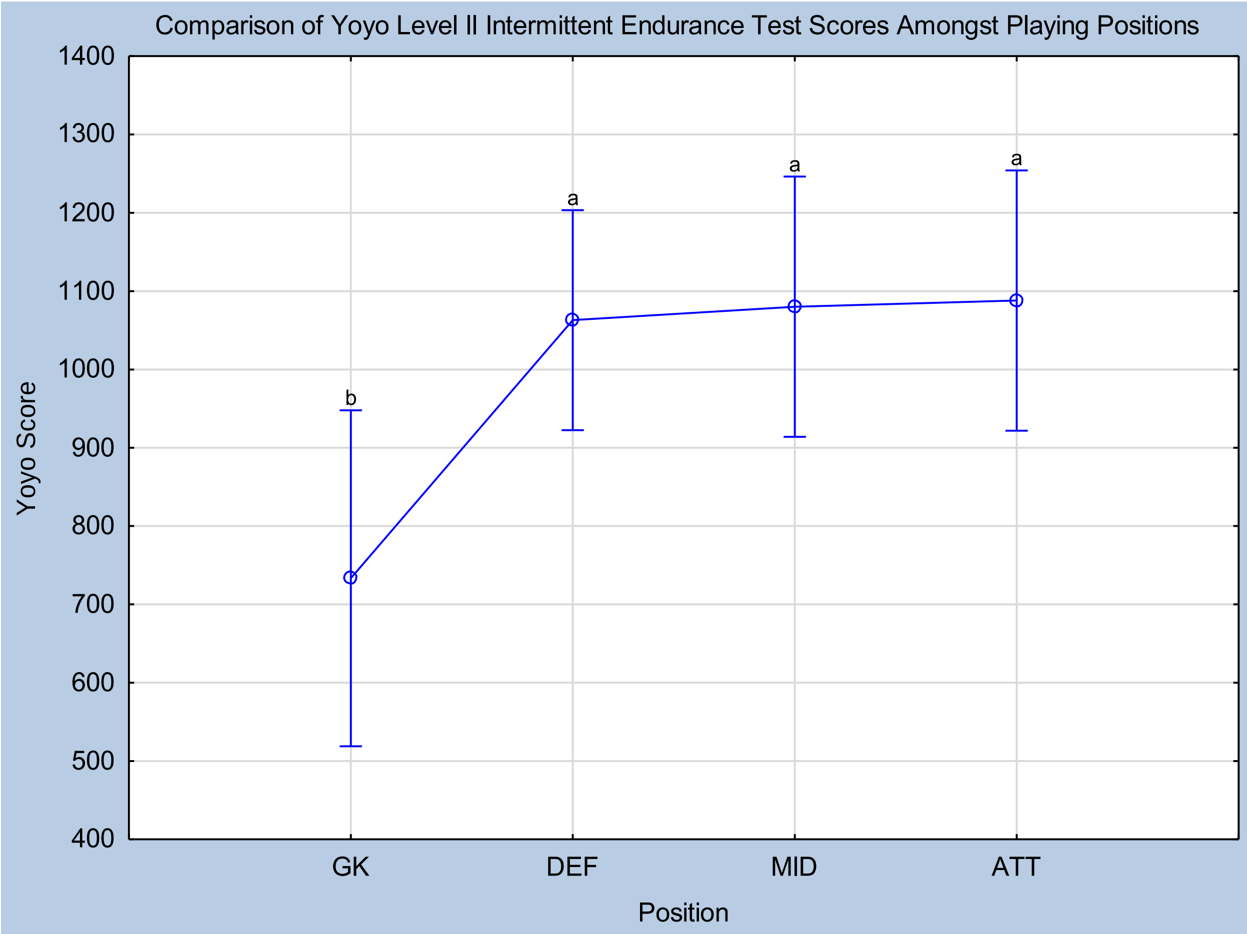

Figure 4-11 **The performance of the goalkeepers against the other three playing positions. Statistically significant difference between performance of goalkeepers on the yoyo II test compared to all other playing positions (P < 0.05).**

Table 4-11 **Table depicting the mean scores of each positional group for the Yoyo2 in which DEF, MID, and ATT.**

	Position				
Yoyo II	GK	DEF	MID	ATT	SQUAD
Distance (m)	733,33 ± 82,19	1062,86 ± 161,22 *	1080 ± 200,80 *	1088 ± 132,42 *	913,08 ± 339,01

*P < 0.05 Statistically significant difference to goalkeepers‟ performance on the Yoyo II.

Summary

In summary, there were several matters of interest for different reasons. On some occasions, there was very little difference between variables when it was hypothesized that there would be large differences between those variables for example; there were no statistically significant differences amongst any playing positions over all time periods and for all endocrine variables and there were no differences amongst the squad as a whole over all time points in terms of their DHEA response. On other occasions it became apparent that one set of data, as was the case with case 26, could skew an entire data set. There were some marked differences particularly within the cortisol response to competitive match-play which will be discussed in-depth in Chapter Five – Discussion. Lastly, the YoyoII provided some interesting data with regards to the goalkeepers performing significantly worse than the other playing positions yet producing similar endocrine response to that test.

Chapter Five

Discussion

Introduction

The present study investigated the effects of varying SSGs, a performance test, and match formats on the endocrine system response of elite soccer players under the age of 23 years old over a seven month period. The primary aim of the study was to determine whether the internal training loads of SSGs of varying sizes differed and whether those training demands equated to the demands of competitive matches in soccer. The secondary aim of the study was to determine whether players of different playing positions experienced different internal training and match loads and whether the training demands of different positions equated to those same positions in match play. This chapter seeks to provide reasonable explanation for the results of this study and the aims of this study will be answered through the in-depth analysis of the research objectives. The discussion of each research objective will provide a platform from which to formulate a final conclusion with regards to the primary and secondary aims of this study.

The chapter will conclude with a discussion of the limitations of the present study and the implications they have on future studies. Furthermore, practical coaching advice will be provided based on the experience of the author at the testing/training location and owing to the author's vested interest in providing practical knowledge to coaches on the characteristics of SSGs as a method for conditioning soccer players. Lastly, specific conclusions will be drawn based on the study's main findings.

Research Objective One

To determine the differences in cortisol responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games.

At the time of writing, and to the best knowledge of the author – this is a novel study in a sense that no other research studies have aimed to investigate the difference in endocrine response amongst soccer SSGs of varying sizes. As such, there are two key components worthy of discussion when analysing this research objective. The first is what differences there may or may not be between SSGs of varying numbers of players and the second being what role cortisol may play in the measurement of training load amongst soccer players. Furthermore, because of the unique nature of this study, direct comparison with other soccer studies became extremely difficult.

It was hypothesized that SSGs with fewer numbers of players would result in increased internal training load compared to SSGs of higher numbers of players. The training plans of Ajax Cape Town FC were constructed under this assumption. Increased internal training load should equate to an increased acute cortisol concentration after exercise in SSGs of fewer numbers of players compared to those with more players. This hypothesis was based on the fact that, bar some conflicting heart rate response data, several common measures of internal training load in soccer; including blood lactate concentration and RPE have indicated that SSGs with fewer numbers of players elicit a greater internal training load response (Aguiar, Botelho, Lago, Macas, & Sampaio, 2012)(Hill-Haas *et al.*, 2011). Salivary cortisol has been recommended by Passelergue and Lac (1999) as an index of training stress (Moreira *et al.*, 2009) and therefore it was hypothesized by the author that acute cortisol concentration response would mirror that of the internal training load markers, such as blood lactate concentration and RPE mentioned above.

The current study showed no statistically significant differences between acute cortisol concentration levels amongst SSGs of varying numbers of players ($p > 0.05$). Moreover, 4v4 and 7v7 SSGs presented with increased cortisol concentration compared to resting values while the 11v11 SSG presented with a decreased cortisol concentration compared to resting values. Similar findings with regards to the 11v11 SSG data in this study were found in a study by Moreira *et al.* (2009) that aimed to determine whether salivary cortisol would increase following a competitive training (11v11) match. The two studies shared several procedural characteristics including; time of day when saliva samples were collected (around 3pm for baseline samples and 5pm for post 11v11 SSG), manner in which samples were collected (unstimulated saliva sampling), storage and analysis of saliva sampling (initially frozen before analysis), abstaining from food or caffeine for a minimum of two hours prior to sample collection and abstaining from exercise for at least 24 hours before sample collection.

However, there were certain key characteristics that the two studies did not share. Firstly, while the players in the current study had age ranges of between 16 and 23 years old, Moreira *et al.* (2009) dealt with adult men with an average age of 23 ± 4 years old. Secondly, levels of participation differed. While both study samples were at the elite playing level, Moreira *et al.* (2009) dealt with professional level players who trained 15 – 28 hours per week compared to 6 – 10 hours per week at Ajax Cape Town FC. Lastly, the duration of 11v11 SSGs differed between the two studies. Ajax Cape Town FC participated in 20min halves compared to 35 min halves of the Sao Paulo team.

In an attempt to explain why cortisol levels did not increase significantly as expected, Moreira *et al.*, (2009 p. 29) suggested that, “It may be reasonable to consider that top-level professional soccer players training systematically and regularly are very well adapted for this type of stress". They go further to suggest that the lack of competitiveness within a training game may have resulted in an insignificant change in cortisol levels throughout the team.

While there is no current literature investigating the endocrine response to SSGs with fewer than 11 players per team, comparison amongst studies becomes very challenging. However, in a study by Splerich, Achtzehn, Buhr, Zinner, Zelle, and Hans-Christer (2012) that examined the salivary cortisol, heart rate and blood lactate response to elite downhill mountain bike racing, it was found that blood lactate response and cortisol response were correlated. The present study and the study by Splerich *et al.* (2012) shared several procedural characteristics; the study samples are of similar ages, both study samples are considered elite in their respective sporting codes, cortisol sampling was done through saliva sampling and the nature of a downhill race could be similar to the intensity of a 4v4 SSG where a large portion of the exercise is spent in the hard zone (high intensity ± 90% of maximum HR) according to HR data (Aguiar *et al.,* 2012; Splerich *et al.,* 2012). The biggest differences between the two studies lies in the type of sport (cycling versus soccer) and the level of competitiveness of the exercise in which the present study took place during training and the study by Splerich *et al.*, (2012) during competition. Nonetheless, Splerich *et al.* (2012 p.47) concluded that, "levels of blood lactate as well as increased concentration of salivary cortisol is a marker for psycho-physiological stress".

In an attempt to draw comparison to the current study, the study by Randers, Nielsen, and Krustrup (2014) which aimed to compare the endocrine response to several SSGs was analysed. Randers *et al.* (2014) used blood lactate (mentioned above as correlating to cortisol response) as a variable in quantifying SSG internal training load. They found that there were no differences in blood lactate response between 3v3, 5v5 and 7v7 SSGs within the team. The results of the present study mirror the results of Randers *et al.* (2014) in the sense that there was no difference between the 4v4 and 7v7 SSG endocrine response. It is suggested that, were the SSGs competitive in nature, as in the studies by Splerich *et al.* (2012) and Moreira *et al.* (2009) that there would have been significant increases in blood lactate and cortisol response compared to resting levels and perhaps differences between 4v4, 7v7 and 11v11 SSGs would have been observed.

Mendham, Duffield, Marino, and Coutts (2015) compared the differences between the acute inflammatory response of rugby league SSGs and cycling. It was reported that cortisol levels were statistically significantly increased ($p < 0.05$) after both SSGs and cycling conditions. While these findings are in contrast to the findings of the present study, it is perhaps best explained through the differing training statuses of the two study populations. As earlier suggested by Moreira *et al.* (2009), the training status may have a role to play in the cortisol response to exercise. Owing to the fact that the study by Mendham *et al.* (2015) was conducted on sedentary, middle-aged, men this might provide an answer as to why the players in the present study did not produce similarly significant increases in cortisol response when exposed to SSGs. Indeed, the two studies were otherwise similar in a sense that both studies used SSGs of between four and seven a side, both SSGs were predicted at inducing an 80-85% HR maximum mean target zone (Mendham *et al.*, 2015; Aguiar *et al.*, 2012) and both sets of SSGs were conducted on similar field sizes (60m x 40m). It is therefore suggested that it was not the type of sport or characteristics of the SSGs that resulted in conflicting results between the present study and the study by Mendham *et al.* (2015), but rather the difference in training status between the study samples.

Research Objective Two

To determine the differences in cortisol responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games in players in different playing positions.

It was hypothesized by the researcher that different playing positions would produce different cortisol responses when subjected to 11v11, 7v7 and 4v4 SSGs. Additionally, it was hypothesized by the researcher that these differences would become more apparent as the SSG became larger in terms of numbers of players based on the fact that specific positional roles would become more clear the larger the field and the more number of players playing. This hypothesis was based largely on the work of Di Salvo *et al.* (2007) and Di Salvo *et al.* (2013) who found that elite soccer players during match-play presented with significantly different results in terms of external loading data (e.g. total distance, distance and time spent in different speed zones, number of accelerations and decelerations) based on their playing positions.

It was found in the present study that there were no differences in acute cortisol response across all SSGs based on playing position. These findings are in line with those of Dellal, Owen, Wong, Krustrup, van Exsel, and Mallo (2012) who found no differences in blood lactate response amongst playing position both in 4v4 SSGs and in friendly 11v11 match play. Dellal *et al.* (2012) offered no suggestions as to why the blood lactate response did not differ between playing positions in both 4v4 and 11v11 SSGs. It is noted by the researcher of this present study that the technical and external loading patterns of the specific playing positions in the study by Dellal *et al.* (2012) did vary according to total distance covered, total distance covered running at high intensity or sprinting and numbers of duels, balls lost, ball possessions and missed passes all differing amongst playing positions. It is therefore suggested by the researcher that the body's internal (endocrine) response may reflect a total training load rather than the individual differences in terms of external training load patterns between the different positions in soccer.

Research Objective Three

To determine the differences in testosterone responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games.

To the best knowledge of the researcher, there are no other studies that have aimed to determine the differences in testosterone response based on the numbers of players in a SSG context, let alone between playing positions. It was hypothesized that testosterone concentrations would decrease after all SSG sessions and more so in the 4v4 than the 11v11 SSG. This hypothesis was formulated after the analysis of an article by Pimenta *et al.* (2012) who found that testosterone concentrations decreased after intense exercise.

Testosterone has, however, been shown to be difficult to fully understand in terms of its role and response to exercise. In a study by Arruda, Aoki, Freitas, Spigolon, Franciscon, and Moreira (2015) which monitored elite, young (14 – 17 year old) soccer players, it was hypothesized that testosterone and strength and power are correlated based on previous research about the hormone. However, contrary to the hypothesis and results of previous authors, Pimenta *et al.* (2015) discovered that while testosterone concentrations decreased amongst the group of young soccer players over the season, the power and strength of those same players increased. Furthermore, in a report released by the Centers for Disease Control and Prevention, it was stated that testosterone concentrations are expected to increase in response to exercise and that its importance within exercise is unknown (Centers for Disease Control and Prevention, 1999).

In the present study it was found that testosterone concentration statistically significantly increased ($P < 0.05$) in response to 7v7 SSGs when compared to baseline when case 26 was included in the data set and that testosterone concentrations did not statistically significantly increase when case 26 was excluded ($P > 0.05$). Additionally, the 4v4 and 11v11 SSGs presented no changes with regards to testosterone concentration in comparison with resting levels. The high level of variance between participants' responses to training became extremely evident when removing one set of data which resulted in a shift in the level of significance of the entire squad. This limitation will be discussed in depth later on in the chapter. Unfortunately no other studies were found that aimed to determine the acute response of testosterone to training amongst soccer players, however several studies have aimed at determining the role of testosterone in match demands and will be discussed later on.

Research Objective Four

To determine the differences in testosterone responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games in players in different playing positions.

As was the case with research objective two, it was hypothesized by the researcher that different playing positions would produce different testosterone responses when subjected to 11v11, 7v7 and 4v4 SSGs. Furthermore, the researcher hypothesized that these differences would become clearer as the SSG became larger in terms of numbers of players based on the fact that specific positional roles would become more clear the larger the field and the more number of players playing. Once again, this hypothesis was based on the findings of Di Salvo *et al.* (2007) and Di Salvo *et al.* (2013) in which elite soccer players during match-play presented with significantly different results in terms of external loading data (e.g. total distance, distance and time spent in different speed zones, number of accelerations and decelerations) based on their playing positions.

In the present study, no statistically significant differences ($P > 0.05$) were found when comparing testosterone response to SSGs amongst the varying playing positions of goalkeepers, defenders, midfielders and attackers. While no other studies have sought to determine the acute difference in testosterone response to SSGs or even exercise amongst soccer players and playing position, it warrants further investigation into the subject. The author suggests that the secretion of testosterone is not dependent on the different external loading demands of specific playing positions, or that the differences in external load amongst playing position is not large enough to yield differing testosterone responses to SSGs. It is hypothesized that the secretion of testosterone is an indicator of total training stress rather than being influenced by individual external cues such as; specific running patterns, speed of movement or distance covered at different intensities.

Research Objective Five

To determine the differences in T:C ratio responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games, matches, yoyo level II, and resting levels over the duration of the season.

The testosterone to cortisol ratio (T:C ratio) has been described in previous works as, "can be used to assess the recovery status of an athlete" (Anderson, Lane, & Hackney, 2016, p. 1504) and, "used in various sports to follow athletes and avoid overtraining" (Banfi & Dolci, 2006, p. 611). While it is clear that the T:C ratio is used on a long-term/ longitudinal scale to monitor fatigue, it is not as clear as to what the acute response - specifically to soccer and SSGs - the T:C ratio has. It was hypothesized by the researcher that the T:C ratio would drop dramatically in response to both SSGs and matches based on an expected sharp increase in cortisol after exercise and decrease in testosterone after exercise (as hypothesized in previous research objectives). In a longitudinal manner, no hypothesis was made as to the resting levels of T:C ratio amongst the team over the duration of the season, rather, the researcher aimed to monitor the resting T:C ratio and report the findings to examine whether the training program of Ajax Cape Town was resulting in any kind of overreaching and possibly overtraining syndrome amongst the players of the team.

The present study found no differences between playing position and T:C ratio in response to any training, match, or performance testing time periods ($p > 0.05$). As such, the team was analysed as a whole rather than within the specific playing positional groups. As a squad, the T:C ratio was statistically significantly lower ($p < 0.01$) after the competitive match when compared to both baseline and yoyoII concentration levels. Additionally, a trend was noticed that the friendly match produced lower T:C ratios when compared to the SSGs and baseline concentrations. Lastly, the resting T:C ratio for the squad over a period of eight months had no statistically significant difference and the resting T:C ratio of the squad presented with 48% increased concentration at the end of the season (0.891ng/ml) against baseline at the beginning of the season (0.603ng/ml) ($p = 0.11$). What is not clear, is the implication for training if an increase (e.g. 48%) is found. Does an increase in 48% perhaps suggest that combined training and match load between testing points needed to be higher? What is the optimal increase/ decrease in T:C ratio between testing points in order to induce maximum physiological adaptation without the risk of overreaching?

When analysing the acute response of T:C ratio to exercise and soccer it is important to note that no studies were found that aimed to monitor the T:C ratio response to SSGs in soccer. A study by Anderson *et al.* (2016) found that in response to exhaustive endurance exercise (96.9 ± 10.8min), 12 elite endurance athletes presented with a statistically significantly decreased T:C ratio in response to exercise ($P < 0.005$). The authors suggested that the length of time of exercise may have a role to play in the T:C ratio response to exercise. In the present study, only the competitive match was anywhere close to the length of time of the endurance exercise protocol in the study by Anderson *et al.* (2016) above. The rest of the sessions were closer to 30min or shorter (except for the friendly game which consisted of two shortened halves of around 30min). Indeed, even the anecdotal observation with regards to the friendly match T:C ratio being lower than those of the SSGs may indicate that duration of exercise may have a marked role in the acute T:C ratio response after exercise. The response of the T:C ratio with regards to match-play will be discussed at length in research objective eight below as the T:C ratio is merely a product of the response of the separate testosterone and cortisol hormones to exercise.

When analysing the chronic or longitudinal aspects of the T:C ratio and its relationship with overtraining, the study by Banfi and Dolci (2006) on elite soccer players over a period of two years provides insight. It is reported by Banfi and Dolci (2006) that two formulas are used to determine overtraining when dealing specifically with T:C ratio as the indicator for overtraining. If an athlete presents with a T:C ratio of less than 0.35×10^{-3} (testosterone measured in nanomoles per litre and cortisol measured in micromoles per litre), or if an athlete's T:C ratio decreases by more than 30% in comparison with their last measurement, it could be an indication of overtraining. Banfi and Dolci (2006, p. 612) stated that, "The use of an absolute threshold is not useful, because athletes rarely, even in extreme performances, show values near or lower than the proposed threshold (of 0.35×10^{-3})".

With this in mind, it is clear to the researcher of the present study that an increase in the squad's T:C ratio of 48% is an indication that the squad as a whole was not in any danger of overtraining in response to the workload of the eight month season because the squad was nowhere near the proposed risk zone of a 30% decrease in T:C ratio since the last measurement. Banfi and Dolci (2006) made a special note that the intra-individual variability of the cortisol, testosterone and T:C ratio (reported as 21%, 9.6% and 12% respectively in their study) is high. They suggested that the variability that can be seen amongst the different hormone readings may be significantly influenced by the biological variability of the subjects. As stated in research objective three, this limitation will be discussed later on with solutions as to how to account for the high intra-individual variability.

Research Objective Six

To determine the differences in dehydroepiandrosterone (DHEA) responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games.

It was stated by Savineau *et al.* (2013 p. 718) that, "In human, DHEA is the most abundant adrenal steroid and serum concentrations of its 3β-sulphate ester (DHEA-S) are approximately 20-fold higher than those of any other circulating steroid hormone". This statement is in agreement with Ponzi *et al.* (2015) who not only stated that DHEA is the most abundant of all the androgen hormones in circulation in the human body, but also that DHEA, much like cortisol, is secreted in response to psychosocial stress and is more stable than cortisol because it is not affected as much by the circadian rhythm. The above factors suggested that DHEA would be easily measurable and provide valuable information to the study when analysed in conjunction with cortisol and testosterone concentrations.

Unfortunately, very little research has been published that seeks to understand the nature of DHEA in response to acute bouts of exercise – and even fewer that deal specifically with soccer. One such study was a study by Thomasson *et al.* (2010), which analysed nine young (20.3 ± 0.4 years) women in response to submaximal exercise in an attempt to determine in serum and saliva DHEA were correlated. In this study, they found that after 120min of cycling at submaximal intensity (50-55% VO_{2MAX}), neither serum nor saliva DHEA and cortisol concentrations were significantly elevated. It was suggested by the author that DHEA was not elevated due to the fact that the exercise intensity was very low and that there were no added psycho-social stressors on the participants who simply cycled on a stationary bike.

A study by Labsy *et al.* (2013) addressed this suggestion directly when it sought to document the cortisol and DHEA responses of nine young (19.9 ± 0.4), male, recreationally trained soccer players over a period of three separate days. The intensity of the exercise in this study was much higher than the intensity of exercise in the study by Thomasson *et al.* (2010) with participants performing 45min running at 70% peak HR, 2 x 15min intervals at 80% peak HR and lastly followed by 5 x 1min intervals at maximum HR. The purpose of this intervention was to simulate the intensity of a normal soccer practice (Labsy *et al.*, 2013). As documented before in research question one, there was a statistically significant increase in cortisol concentration after exercise ($P < 0.01$), but interestingly, there was no statistically significant increase in DHEA concentration after exercise amongst the group. In an attempt to explain why cortisol concentration was increased after exercise but not DHEA concentration, Labsy *et al.* (2013 p. 264) stated that, "may be due to the time of collection, with a return to basal values in the post-exercise sample, possibly linked to the shorter elimination half-life of DHEA compared with cortisol". In the study by Labsy *et al.* (2013), samples were collected 30min after exercise which is similar to the protocol of the present study which aimed to have all players" saliva samples on ice within 30min post-exercise.

The findings of the present study showed no statistically significant changes in DHEA amongst the squad between all SSG time points when compared to baseline. These results were in line with the findings of Labsy *et al.* (2013) and Thomasson *et al.* (2010) above. As of yet it is uncertain as to why DHEA does not provide a response to soccer SSGs as cortisol does.

Research Objective Seven

To determine the differences in dehydroepiandrosterone (DHEA) responses between 11 vs 11, 7 vs 7 and 4 vs 4 small sided games in players in different playing positions.

In the present study, no statistically significant differences (P > 0.05) were found when comparing DHEA response to SSGs amongst the varying playing positions of goalkeepers, defenders, midfielders and attackers. While no other studies have sought to determine the acute difference in DHEA response to SSGs or even exercise amongst soccer players and playing position, it warrants further investigation into the subject.

Research Objective Eight

To examine the endocrine response to competitive and friendly match-play amongst the squad as a whole.

While literature relating to SSGs and the endocrine system response amongst soccer players is limited, there is no shortage of literature documenting the human endocrine response to soccer matches. Owing to the fact that no observable differences were found between endocrine response and playing position over all time periods, team data as a whole will be highlighted during this section rather than individual playing position data.

It was hypothesized that the endocrine response would be markedly higher in competitive match play in comparison with SSGs and that friendly (pre-season matches) matches would provide a middle ground between the two. This hypothesis was based largely on the concept that while SSGs are designed to reflect the specific match demands of a regular soccer match, they do not provide the same level of stress on the players because SSGs lack the competitive nature that the friendly and competitive matches provide (Haneishi, Fry, Moore, Schilling, Li, & Fry, 2007)**.** Haneishi *et al.* (2007) examined cortisol and stress responses in both game and practice environments amongst female collegiate soccer players. While their training sessions did not consist of SSGs exclusively, they did play both 3v3 and 6v6 SSGs during the session. They found that while cortisol was elevated in both training and matches when compared to resting levels, that the match response was greater than the training response by approximately 250%. Haneishi *et al.* (2007 p. 587) concluded that, "the greater psycho-physiological stress during a competitive soccer game compared with a typical practice session may permit coaches and athletes to more fully appreciate the total stress accompanying actual competition".

Further studies documenting the cortisol response of soccer players to matches include a study by Edwards *et al.* (2006) who found that amongst young, varsity soccer playing men (18 – 22 years old) a competitive match resulted in statistically significantly increased cortisol concentrations ($p < 0.01$). These findings were similar to those of Thorpe and Sunderland (2012) who found that cortisol concentration increased by 78% compared to baseline levels after a competitive match in seven, semi-professional soccer players (although not significant at $p = 0.1$). Thorpe and Sunderland (2012 p. 2787) believed that, "the increase in cortisol level could be explained by the extensive muscle damage because of cortisol's anti-inflammatory properties or the combination of physical and psychological factors could have produced the observed elevations in salivary cortisol". They go on to state that the reason the difference between baseline and post-match cortisol concentration was not significant was because of a (typically) large inter and intra individual variation.

In the current study, it was evident that cortisol concentration was statistically significantly increased immediately after a competitive match amongst the squad as a whole ($p < 0.01$). This finding, along with the finding that cortisol concentration did not statistically significantly increase in response to the various SSGs, is similar to the findings of the studies above wherein training did not seem to produce the same stress response than the competitive environment. Interestingly, the friendly match in which Ajax competed against another club in a pre-season match did not result in a statistically significant increase in cortisol concentration compared to baseline values. The mechanisms and possible explanations for these results will be discussed later on in the chapter.

With regards to testosterone and match-play, there are several studies that have produced conflicting results to those measured in the present study. In the present study it was found that acute testosterone concentration amongst the team did not increase ($p > 0.05$) in response to competitive or friendly match-play. However, in a study by Thorpe and Sunderland (2012) in which seven semi-professional soccer players (25 ± 6 years old) competed in a soccer match it was found that testosterone was increased by 44% compared to resting values. These findings are similar to those of Edwards *et al.* (2006) who Thorpe and Sunderland (2012) mention as a study that similarly documented increased testosterone concentrations after competitive match-play. Thorpe and Sunderland (2012 p. 2788) stated that it could be, "a combination of factors including hemoconcentration, a decrease in metabolic clearance rate, and an increase in secretion" that resulted in the increased testosterone concentration after match-play amongst their team. They go on to suggest that the 90min match in which players performed up to 69 sprints and resulted in substantial muscle damage may have stimulated the mechanisms more associated with strength exercise than aerobic exercise resulting in increased testosterone concentration. Edwards *et al.* (2006 p. 140) provided another possible explanation for the concurrent increased cortisol and testosterone concentrations during match-play and that is that they attribute some of the increase in testosterone to, "the conversion of DHEA and DHEA-S whose adrenal secretion is stimulated by the same ACTH that stimulates the secretion of cortisol”. Arruda *et al.* (2016) presented similar findings when analysing elite, young (19.3 ± 0.7 years) futsal players. They found that the young men presented with not only significantly increased cortisol, but significantly increased testosterone in response to match-play regardless of playing at home or away from home.

One study that reported similar findings to those of the present study was a study conducted on 24 elite male soccer players (21.1 ± 1.2 years old) by Ispirlidis *et al.* (2008) in which the inflammatory response to a soccer match was analysed. It was reported by Ispirlidis *et al.* (2008) that while cortisol concentration significantly increased after the match ($p < 0.05$), testosterone exhibited no clear indicators of change. No explanation was offered by the authors as to why there was no change in testosterone concentration after a match. It is clear that further investigation into the effects of soccer match-play on testosterone concentration is warranted. This will be discussed later on in the future studies section of the chapter.

To the best of the authors knowledge, very little has research has been conducted into the response of DHEA to match-play in soccer players. In a review on salivary hormones and physical exercise research by Gatti and De Palo (2011) it was stated that both testosterone and DHEA are indicators of stress and training load. Gatti and De Palo (2011) stated that in a competitive handball match between elite women, both DHEA and testosterone concentrations did not significantly change. These findings are in line with the findings of the current study in a sense that neither testosterone nor DHEA significantly changed compared to baseline in either the friendly or competitive matches ($p > 0.05$). In an attempt to draw comparison to the present study, a study by McHale, Zava, Hales, and Gray (2016) on juvenile boy soccer players ($n = 17$; 8 – 10 years old) was analysed. In the study by McHale *et al.* (2016), it was found that DHEA concentrations significantly increased in a response to both training and match-play. These findings are in contrast with the findings of the present study and that, along with the fact that cortisol concentration did not increase in response to exercise and match-play in the study by McHale *et al.* (2016), may be as a result of the different ages of the study samples.

Research Objective Nine

To examine the endocrine response to competitive and friendly match-play amongst the different playing positions.

To the best knowledge of the author, no studies have been published that aim to determine the differences in cortisol, testosterone and/or DHEA response in relation to playing position. Additionally, no statistically significant differences were found between playing position and endocrine responses in this study. Possible explanations for these findings will be discussed later on in this chapter.

Research Objective Ten

To determine endocrine responses of the soccer players on the Yoyo Level II test.

The YoyoII test presented with no significant differences amongst playing positions in terms of hormone response (testosterone, cortisol and DHEA) when compared to baseline ($P > 0.05$) even though goalkeepers performed significantly worse than any other position in terms of distance run on the test ($P < 0.05$). However, when analysing the squad as a whole, the competitive match resulted in a statistically significantly increased cortisol concentration in comparison to the YoyoII and a statistically significantly decreased T:C ratio compared to the YoyoII. In fact, the YoyoII yielded comparable levels to baseline concentrations in cortisol, testosterone, T:C ratio and DHEA. These results were of interest because of the conclusion Bradley *et al.* (2011 p. 977) who stated that, "the Yo-Yo IE2 test was shown to provide a sensitive tool that not only relates to match performance but can also differentiate between performance of players in various standards, stages of the season, playing positions and age groups". Indeed, Bradley *et al.* (2011) sought out to establish whether the YoyoII was able to quantify the capacity of elite soccer players to perform intense intermittent exercise and concluded that it could. Through the analysis of the results of the present study however, it is noted that the YoyoII was not as good of a measure of the demands of soccer match-play as hypothesized by Bradley *et al.* (2011). The YoyoII failed to induce the cortisol response of that after match-play. The author suggests that this might be explained by the difference in time of the two different exercises (10 – 20min for YoyoII and 90min for competitive match) but is more likely to do with internal response to training that will be discussed further later on in this chapter.

Primary and Secondary Aim

The primary aim of the study was to determine whether the internal training loads of SSGs of varying sizes differed and whether those training demands equated to the demands of competitive matches in soccer. Through the analysis of the different hormones over all of the different time points, it is apparent that the internal training loads of the varying SSGs did not differ to the extent that was originally hypothesized. With case 26 excluded; 4v4, 7v7 and 11v11 SSGs did not present with any significantly different cortisol, testosterone, T:C ratio or DHEA changes. The demands of the matches – both friendly and competitive – seemed to outweigh the demands of the SSG training sessions based largely on an increased cortisol (and thus T:C ratio) response to match-play in comparison to baseline. It is suggested that the marked increase in cortisol and decrease in T:C response to matches and not SSGs is due to the fact that training does not present the same level of total stress that a match does which includes but is not limited to; emotional stress, pyscho-physiological stress, and muscle damage because of the competitive nature of a match (Moreira *et al.* 2009; Gatti and De Palo, 2011; Haneishi *et al.* 2007; Thorpe and Sunderland, 2012). Haneishi *et al.* (2007) illustrated this relationship between match-play and total stress through the monitoring of somatic and cognitive state anxiety and found that soccer athletes exhibited higher levels of anxiety in match conditions compared to training conditions. These findings suggested that cortisol is better suited for the overall monitoring of stress, rather than the physiological monitoring of stress alone.

The secondary aim of this study was to determine whether players of different playing positions experienced different internal training and match loads and whether the training demands of different positions equated to those same positions in match play. Unequivocally it can be said that the differing playing positions had no effect on the internal response to SSGs and match-play. At no time point were any differences in positional endocrine response when compared to one another observed. It is suggested by the author that because all players amongst the different playing positions are exposed to the same variables (duration of session, time of day, relative emotional state, levels of anxiety) there is no change in internal endocrine response amongst playing position. The only variable that these players do not share is the fact that they play in different positions on the field. Indeed, if one observes the findings of this study, it is only cortisol that significantly changed in response to match-play. Therefore the author hypothesizes that the psychological and emotional stress of the competitive environment has just as much, if not more influence over the cortisol response to exercise than the specific positional roles amongst the players.

Summary

The endocrine response to SSGs and match-play is extremely intricate and is not only affected by the physical requirements of each soccer player within his position. Cortisol appears to be the hormone that changes most in response to both SSGs and match-play and is statistically significantly higher in matches than in SSG training - suggesting that match loads far outweigh training loads. This is likely to do with the fact that match loads provide a greater total stress than SSGs based on the competitive environment. No differences are recorded between playing position and endocrine response to SSGs and match-play. This suggests that levels of anxiety and emotional stress may play a larger role in the endocrine response to exercise than the differing movement characteristics of the various playing positions. The T:C ratio over the eight month season presented with a 45% increase which is considered at no risk of overtraining over the season. This suggests the training program of Ajax Cape Town FC was not over strenuous and the coaches have some freedom to perform more strenuous training sessions in the future. This suggestion is supported by the fact that SSG sessions did not significantly increase cortisol concentration or decrease the anabolic to catabolic (T:C) ratio amongst the team. Testosterone and DHEA require further analysis to determine their roles with regards to internal training load. Large individual variability (see all figures in chapter 4) necessitates the need for an individual, repeated measures approach when analysing endocrine response to SSGs and match-play amongst soccer players (Thorpe and Sunderland, 2012). The YoyoII test did not mirror the demands of a competitive match suggesting either that it is not a suitable measure for physiological fitness amongst soccer players or that it does not provide the total stress stimulus that a competitive match provides.

Limitations and Future Studies

Most likely the biggest limitation of this study was the large intra and inter-individual variability within the data set. While this is quite normal in studies of this nature, it warrants the need for future studies which measure fewer numbers of players, but more frequently and over more time points. This should provide a better understanding of which variables are truly responsible for the change in endocrine concentrations in response to SSGs and match- play.

Additionally, not all 22 players were tested at each time point, but rather a random selection of up to 11 players per time point due to financial constraints and the 11v11 format of matches.

A second limitation of this study was the fact that only endocrine response to training was measured. Future studies should make use of a multitude of internal training load measures including HR, RPE, questionnaires, blood lactate and CK concentrations. Additionally, these internal training load measures should be compared with the external training load characteristics of the different SSGs and matches in order to provide a more complete understanding of training and match loads in soccer. While all warm-ups were similar, no warm-up was exactly the same – this is an example of how dynamic the training and match environment in soccer truly is and other limitations with regards to training and match environment included; differing levels of coach encouragement, some players stopping training or matches to drink water, substitutions, weather and player motivation. It is important to control as many variables as possible but also important to note that in the sporting environment this is not always possible.

Another limitation is the fact that the researcher was unable to control the participants' exercise and eating/ drinking habits prior to them arriving at the sessions. Although players were instructed not to do any exercise the day before a session and to avoid eating or drinking prior to the session, it was impossible to monitor each and every player. Future studies should aim to control these factors as best as possible.

Another major limitation of the study was the fact that only one of each of the 4v4, 7v7, 11v11, YoyoII, friendly, and competitive match were recorded. This was due to the financial implications of performing another round of testing. Ideally future studies should aim to test each session on multiple occasions ensuring that each session is as similar as possible to one another. Owing to the cost of hormone analysis, a future study into the correlation between cortisol, testosterone and DHEA to common, more cost effective measures of internal training load such as HR, sRPE and blood lactate or combined measures should be done. The researcher suggests that future studies aim to determine the ideal change in T:C ratio percentage between testing points in order to stimulate maximal physiological adaptation amongst the players without inducing symptoms of overreaching or chronic overtraining.

The researcher suggests that the age range of the participants (16-23 years old) may have provided a limitation to the study based on age related differences in the endocrine system response to training and match loads.

Practical Implications

It is acknowledged that the findings relate to this specific research project and cannot necessarily be extrapolated to other clubs. However, based on the findings of the current study, a few suggestions will be made. Coaches should consider using combined measures of monitoring training load and match load as opposed to only endocrine response. Questionnaires, external loading data (GPS, time-motion analysis, accelerometers etc.) and other means of monitoring internal training load (HR, sRPE, blood lactate etc.) should all be used to provide a broader picture of total training load. Furthermore, coaches should attempt to simulate the competitive environment as best as possible when training in order to stimulate comparable internal training loads to those of matches – particularly when doing overloading training sessions – because the current training loads of the SSGs were not comparable to the demands of matches. Because differences in endocrine response between 4v4, 7v7 and 11v11 SSGs were not significant, coaches could use these different sizes of SSGs based on the technical and tactical differences they produce rather than the internal adaptation they will produce. Coaches should make use of friendly matches or SSGs against other clubs or teams to simulate the competitive environment of a match particularly in pre- season when trying to maximize physiological adaptation.

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Appendix A

Consent to Participate in Research

Small-sided games: Comparing training load and match demands in elite u19 South African soccer players

You are invited to participate in a research study conducted by me, Simon de Waal (MSc Sport Science) from the Department of Sport Science at Stellenbosch University. The results obtained from the study will contribute to the thesis for my Master's degree. You were selected as a possible participant in this study because you are a member of the Ajax Cape Town FC u19 squad for the 2014 season.

a) AIM OF THE STUDY

The primary aim of the study is to determine whether the training loads of games of different sizes vary and whether those training demands equate to the demands of competitive soccer games.

b) PROCEDURES

If you agree to participate in this study, I would ask you to help with the following:

Global positioning system (GPS) data gathering. Allow data to be gathered from you via GPS units for the entire duration of field training sessions and match-play during the pre- season. Each GPS unit will be held in place in the upper back region between the scapulae (shoulder-blades) by a padded neoprene harness provided by GPSports. This data will include heart rate information from during the sessions and matches.

Video data analysis. Allow the researcher access to video footage of certain training sessions and pre-season matches.

Data gathering during recovery. Subjective rating of fatigue will be recorded on a weekly basis after specific small-sided game training sessions and after matches during pre-season/ You will be asked to provide a score out of 10 using the session Rate of Perceived Exertion (sRPE) scale.

Cortisol, testosterone and DHEA gathering. A saliva sample will be required of you immediately post-training/post-match at certain times during the pre-season. This will occur on six different occasions.

c) POTENTIAL RISKS AND DISCOMFORTS

There are no discomforts associated with the data gathering methods used. The GPS units enclosed in neoprene vests should not cause discomfort due to their small size and since you are used to wearing protective clothing. Saliva sampling will require a swab from the inner cheek for analysis; there is no risk from this process and the testers will wear protective gloves.

The data that will be collected will only be used to monitor load and fatigue during training and matches. It will not affect your chances to be selected for the team.

d) POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

You will not benefit directly from the study. The study will benefit science and the sporting society. The results will provide coaching with the necessary knowledge to provide players on the professional level with better periodization programs and training loads specific to their positions. This will allow for optimal performance through improved conditioning techniques and knowledge of fatigue and recovery.

e) PAYMENT FOR PARTICIPATION

You will not receive payment for your participation in the study.

f) 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 storing data on a password-protected personal computer. Only the researcher and the study leader will have access to the data. The data will remain anonymous at all times.

If the research paper is published, the data will be reported for the group as a whole.

g) PARTICIPATION AND WITHDRAWAL

You can choose whether or not to be a part of this study. If you volunteer to participate in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you do not want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise that warrant doing so.

h) IDENTIFICATION OF INVESTIGATORS

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

Simon de Waal (Mobile: 083 260 23 24; Address: 4 Bayview Road, Somerset West; E-mail: 16240294@sun.ac.za), or Dr Ranel Venter (Mobile: 083 309 28 94; E-mail rev@sun.ac.za).

i) RIGHTS OF RESEARCH PARTICIPANT

You may withdraw you 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 Malene Fouche (mfouche@sun.ac.za; 021 808 46 22) at the Stellenbosch University Division

for Research Development.

SIGNATURE OF RESEARCH PARTICIPANT

The information above was described to me by Simon de Waal in English 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.

____

Name of Participant

____   _______________

Signature of Participant   Date

SIGNATURE OF LEGAL GUARDIAN

The information above was described to me by Simon de Waal in English 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 my child participating in this study. I have been given a copy of this form

____

Name of Legal Guardian

____ _______________

Signature of Legal Guardian Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to:

____

He was encouraged and given ample time to ask me any questions. This conversation was conducted in English.

____ _______________

Signature of Investigator Date

Appendix B

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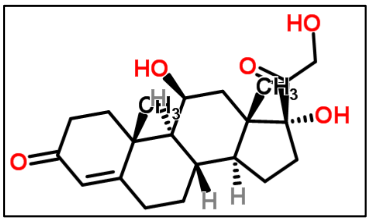
Determination of Cortisol, DHEA and Testosterone in Saliva samples after liquid-liquid (LL) extraction on an Ultra-High-Performance Liquid Chromatographic Method (UPLC) with Mass Spectrometric (MS/MS) detection.

Reference Standards

The following reference standards was obtained for establishing calibration samples, quality control samples and infusion stocks.



Source: http://www.chemspider.com

Analyte: Cortisol

Systematic Name: (11β)-11,17,21-Trihydroxypregn-4-ene-3,20-dione

Chemical composition: $C_{21}H_{30}O_5$

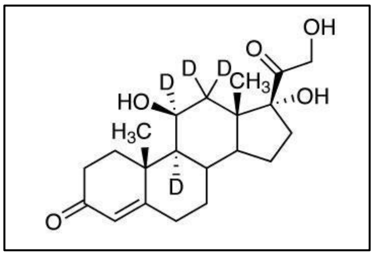
Monoisotopic mass: 362.20932 Da

Expiry date: June 2017

Batch Number: SLBD0859V

Supplier: Sigma-Aldrich

Purity: ≥ 98%



Source: http://www.isotope.com

Internal Standard: Cortisol -9, 11, 12, 12 –d4 (referred to as D4)

Systematic Name: 11,17,21-Trihydroxy(9,11,12,12-2H4)pregn-4-ene-3,20-dione

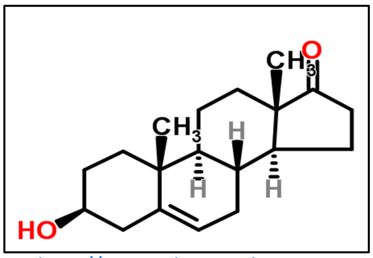
Chemical composition: $C_{21}H_{26}D_4O_5$

Monoisotopic mass: 366.234436 Da

Supplier: Cambridge Isotope Laboratories, Inc.

Purity: 98%

Analyte: DHEA



Source: http://.www.chemspider.com

Chemical composition: $C_{19}H_{28}O_2$

Monoisotopic mass: 288.208943 Da

Expiry date: Feb 2019

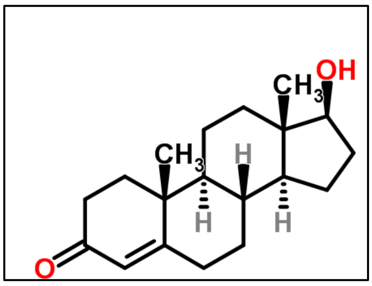
Batch Number: SLBD0859V

Supplier: Sigma-Aldrich

Purity: ≥ 99%

Batch Number: SLBG0104V

Analyte: Testosterone



Source: http://.www.chemspider.com

Chemical composition: $C_{19}H_{28}O_2$

Monoisotopic mass: 288.208923 Da

Expiry date: N/A

Batch Number: SLBD0859V

Supplier: Sigma-Aldrich

Purity: ≥ 99%

Batch Number: BCBL3419V

In-house prepared reagents and buffers

Mobile phase:

Gradient chromatography was applied with mobile phases prepare freshly for each run. Mobile phase A:70 % Methanol and mobile phase B 30 % (10mM) Ammonium Bicarbonate.

Matrix

A simulated saliva matrix was prepared using Bovine Serum Albumin (BSA) 0.1%; w/v (Ray *et al*., 2011)*

Stock solutions:

1000 µg/ml cortisol stock in

Methanol. 1000 µg/ml DHEA stock

in Ethanol.

1000 µg/ml Testosterone in

Methanol.100 000 ng/ml D4 stock

in Methanol.

Instrument parameters/Chromatography conditions

Samples were analysed on a Waters Acquity™ UPLC, connected to a Waters Acquity™ Triple Quad Detector (TQD) with electrospray ionisation (ESI) operating in the positive (+) mode

MS conditions:

Flow rate 0.55 ml/min

Column Oven 40 °C

Column Phenomenex Kinetex 2.6µm C18 100A, 100 x

4.6 mm. Run time 6.50 mins

Injection volume

10 µl Desolvation

temp

500 °C Ion source

temp

140 °C

Elution method Gradient

separation Detection MS/MS

Collision Gas Argon

Cone Gas Nitrogen

Scan Mode: MRM.

Dwell time: 0.015

seconds. Capillary Voltage:

1.0 kV.

Transition specific MS settings:

	Cortisol	DHEA	Testosterone	D4
Transitions (precursor > product ions)	363.11>120.84	289.04>90.97	289.10>108.84	367>120.97
Cone Voltage (Volts)	26	24	34	32
Collision energy (Volts)	58	46	28	26
Predicted Retention time	4.0 mins	5.10	5.10	4.0 mins

Calibrators and Quality control samples:

The stock solutions of Cortisol, DHEA, Testosterone was used to prepare a calibration range of 7 calibrators between 30ng/ml as the upper limit of quantification (ULOQ) and 0.200ng/ml as the lower limit of quantification(LLOQ). Quality control (QC) samples were prepared from stock solutions at high (24.0), medium (12.0) and low (0.600) concentrations in duplicate lank samples (matrix with ISTD) and double blank (only matrix) samples were also included in each batch

Sample Preparation:

Study samples (unknowns) were stored frozen before processing. On the day of processing samples weredefrosted at room temperature. Calibrators and QC samples were prepared fresh according. Samples were centrifuged saliva samples at 1200 rpm for 10 mins before use to remove any debris. After centrifugation 400 µl of each sample (incl. calibrators and QCs) was aliquoted to clean glass tubes. ISTD (100µl D4-solution) was added to represent 30.0 ng/ml in the final sample matrix. A liquid-liquid extraction was performed on the sample by adding 3.0 ml of tert-methyl-butyl ether (TMBE) to each tube. After addition of TBME samples were vortexedfor 2 mins and then centrifuged for 5 mins at 1200rpm. The aqueous layer was frozen in a -80°C freezer (for at least 30 mins where after top layer of unfrozen organic phase was decanted into clean glass tubes. The organic phase was then evaporate to dryness with Nitrogen gas in a nitrogen dryer (TurboVap) at 30°C for approximately 30 mins. The residues were reconstituted with 200µl mobile phase (1:1 ratio of aqueous: organic) and vortexed for 15 seconds each before adding the samples to injector vials fitted with a 200ul insert. The vials were sealed and placed in the sample manager of the Waters Acquity™ UPLC operated at 4°C before injecting the samples into the UPLC system.

Samples are quantified based on response area using MassLynx V4.1. A calibration curve was constructed for each batch and all unknowns and QCs were quantified based on the integrated area of its chromatogram, back calculated from this curve.

* Julie A. Ray,□,1, Mark M. Kushnir, Alan L. Rockwood and A. Wayne Meikle. Analysis of cortisol, cortisone and dexamethasone in human serum using liquid chromatography tandem mass spectrometry and assessment of cortisol: Cortisone ratios in patients with impaired kidney function. Clinica Chimica Acta 412 (2011) 1221–1228

Appendix C

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Approval Notice

Stipulated documents/requirements

25-Aug-2014

De Waal, Simon J

Proposal #: HS1079/2014

Title: Small-sided games: Comparing training load and match demands in elite u19 South African soccer players.

Dear Mr Simon De Waal,

Your **Stipulated documents/requirements** received on **14-Aug-2014**, was reviewed by members of the **Research Ethics Committee: Human Research (Humanities)** via Expedited review procedures on **25-Aug-2014** and was approved.

Sincerely,

Clarissa Graham

REC

Coordinator

Research Ethics Committee: Human Research (Humanities)

Appendix D

Cohen's D test for effect size table in which cortisol response of the squad was compared between all time points.

	Baseline pre season	11v11	7v7	4v4	Baseline end season	Yoyo level 2	Competitive	Friendly
Friendly	0.86(large)	0.91(large)	0.19(small)	0.21(small)	0.89(large)	0.99(large)	0.79(large)	
Competitive	1.57(huge)	1.57(huge)	0.74(medium)	0.96(large)	1.62(huge)	1.72(huge)		0.79(large)
Yoyo level 2	0.09(negligible)	0.04(negligible)	0.35(small)	0.73(medium)	0.07(negligible)		1.72(huge)	0.99(large)
Baseline end season	0.14(negligible)	0.09(negligible)	0.31(small)	0.64(medium)		0.07(negligible)	1.62(huge)	0.89(large)
4v4	0.66(medium)	0.68(medium)	0.07(negligible)		0.64(medium)	0.73(medium)	0.96(large)	0.21(small)
7v7	0.39(small)	0.33(small)		0.07(negligible)	0.31(small)	0.35(small)	0.74(medium)	0.19(small)
11v11	0.06(negligible)		0.33(small)	0.68(medium)	0.09(negligible)	0.04(negligible)	1.57(huge)	0.91(large)
Baseline pre season		0.06(negligible)	0.39(small)	0.66(medium)	0.14(negligible)	0.09(negligible)	1.57(huge)	0.86(large)

Cohen's D test for effect size table in which testosterone response of the squad was compared between all time points.

	Baseline pre season	11v11	7v7	4v4	Baseline end season	Yoyo level 2	Competitive	Friendly
Friendly	0.05(negligible)	0.45(medium)	0.96(large)	0.43(medium)	1.23(very large)	1.26(very large)	1.67(huge)	
Competitive	0.99(large)	1.27(very large)	0.08(negligible)	1.45(huge)	0.37(small)	0.12(negligible)		1.67(huge)
Yoyo level 2	0.91(large)	0.94(large)	0.16(small)	1.03(large)	0.2(small)		0.12(negligible)	1.26(very large)
Baseline end season	0.8(large)	0.85(large)	0.31(small)	0.97(large)		0.2(small)	0.37(small)	1.23(very large)
4v4	0.25(small)	0.08(negligible)	0.81(large)		0.97(large)	1.03(large)	1.45(huge)	0.43(medium)
7v7	0.87(large)	0.77(large)		0.81(large)	0.31(small)	0.16(small)	0.08(negligible)	0.96(large)
11v11	0.28(small)		0.77(large)	0.08(negligible)	0.85(large)	0.94(large)	1.27(very large)	0.45(medium)
Baseline pre season		0.28(small)	0.87(large)	0.25(small)	0.8(large)	0.91(large)	0.99(large)	0.05(negligible)

Cohen's D test for effect size table in which T:C Ratio response of the squad was compared between all time points.

	Baseline pre season	11v11	7v7	4v4	Baseline end season	Yoyo level 2	Competitive	Friendly
Friendly	0.58(medium)	0.83(large)	0.8(large)	0.34(small)	1.17(very large)	1.49(huge)	0.08(negligible)	
Competitive	0.54(medium)	0.83(large)	0.8(large)	0.29(small)	1.18(very large)	1.52(huge)		0.08(negligible)
Yoyo level 2	0.74(medium)	0.62(medium)	0.19(small)	1.34(very large)	0.18(small)		1.52(huge)	1.49(huge)
Baseline end season	0.53(medium)	0.38(small)	0.06(negligible)	0.98(large)		0.18(small)	1.18(very large)	1.17(very large)
4v4	0.32(small)	0.61(medium)	0.63(medium)		0.98(large)	1.34(very large)	0.29(small)	0.34(small)
7v7	0.37(small)	0.22(small)		0.63(medium)	0.06(negligible)	0.19(small)	0.8(large)	0.8(large)
11v11	0.18(small)		0.22(small)	0.61(medium)	0.38(small)	0.62(medium)	0.83(large)	0.83(large)
Baseline pre season		0.18(small)	0.37(small)	0.32(small)	0.53(medium)	0.74(medium)	0.54(medium)	0.58(medium)

Cohen's D test for effect size table in which DHEA response of the squad was compared between all time points.

	Baseline pre season	11v11	7v7	4v4	Baseline end season	Yoyo level 2	Competitive	Friendly
Friendly	0.19(small)	0.44(medium)	0.16(small)	0.11(negligible)	0.07(negligible)	0.27(small)	0.33(small)	
Competitive	0.41(medium)	0.15(negligible)	0.06(negligible)	0.35(small)	0.23(small)	0.(negligible)		0.33(small)
Yoyo level 2	0.39(small)	0.12(negligible)	0.06(negligible)	0.31(small)	0.21(small)		0.(negligible)	0.27(small)
Baseline end season	0.22(small)	0.14(negligible)	0.12(negligible)	0.13(negligible)		0.21(small)	0.23(small)	0.07(negligible)
4v4	0.1(negligible)	0.33(small)	0.2(small)		0.13(negligible)	0.31(small)	0.35(small)	0.11(negligible)
7v7	0.28(small)	0.04(negligible)		0.2(small)	0.12(negligible)	0.06(negligible)	0.06(negligible)	0.16(small)
11v11	0.36(small)		0.04(negligible)	0.33(small)	0.14(negligible)	0.12(negligible)	0.15(negligible)	0.44(medium)
Baseline pre season		0.36(small)	0.28(small)	0.1(negligible)	0.22(small)	0.39(small)	0.41(medium)	0.19(small)

Appendix E

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Jan 20, 2017

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Licensed Content Publication	Journal of Strength and Conditioning Research
Licensed Content Title	Comparing the Physical Demands of Friendly Matches and Small-Sided Games in Semiprofessional Soccer Players
Licensed Content Author	David Casamichana, Julen Castellano, and Carlo Castagna
Licensed Content Date	Mar 1, 2012
Licensed Content Volume Number	26
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Type of Use	Dissertation/Thesis
Requestor type	Individual
Portion	Figures/table/illustration
Number of figures/tables/illustrations	1
Figures/tables/illustrations used	Figure 2 p. 840
Author of this Wolters Kluwer article	No
Title of your thesis / dissertation	Endocrine Response to Small-Sided Games and Match Play in Elite u19 South African Soccer Players
Expected completion date	Mar 2017
Estimated size(pages)	130
Requestor Location	Simon de Waal Coetze Building Coetzenburg Road Stellenbosch, Western Cape 7600 South Africa Attn: Simon de Waal
Publisher Tax ID	4070265758
Customer VAT ID	ZA9201045285082
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