The effects of intermittent fasting during Ramadan on performance related to football.

By

David Wilson

Liverpool John Moores University
School of Sport and Exercise Sciences

Submitted to the School of Sport and Exercise Sciences for the degree of:
Doctor of Philosophy (PhD).

Liverpool, 2007

Liverpool John Moores University
School of Human Sciences
Centre for Sport and Exercise Sciences

The undersigned certify that they have read, and recommend to the Centre of Sport and Exercise Sciences for acceptance, of Doctor of Philosophy (PhD).

The effects of intermittent fasting during Ramadan on performance related to football.

Submitted by **David Wilson**
for the degree Doctor of Philosophy (PhD).

Project Supervisor : ....

Project Tutor : ....

Assessor : ....

External Examiner : ....

Date ....../....../......

Copyright and Disclaimer

No portion of the work referred to in this major project has been submitted in support of an application for another degree or qualification of this or any other university or institute of learning.

This project was supervised by a member of academic staff, but essentially is the work of the author. The project is undertaken primarily as a training exercise in the use and application of research techniques. Views expressed are those of the author are not necessarily those of any other member of the School of Sport and Exercise Sciences.

Abstract

During the 9th lunar month of each year around 1 billion Muslims adhere to the religious 4-week festival of Ramadan, which is considered as a time for empathy for those less fortunate, a time for restraint, and goodwill. The main focus of the religious intervention of Ramadan is the intermittent fast whereby, each day between dawn and sunset nutritional abstinence is practiced. Empirical evidence from experienced soccer coaches in Qatar has indicated that the 4-week intermittent fast during Ramadan impedes the quality and quantity of training, as well as match play. However, there has been lack of attention directed to the consequences associated with Ramadan and football (soccer) players. Greater understanding of the consequences of Islamic soccer players adhering to lifestyle changes and intermittent fasting would facilitate soccer coaches in a systematic approach to addressing potential negative performance effects associated with Ramadan in future soccer-seasons.

In order to address the research problem, a soccer-specific battery of tests was required; as there is no established gold standard battery of soccer-specific field tests preliminary technical and methodological studies were required. In Study-1 a soccer-specific anaerobic capacity field test (*Liverpool Anaerobic Speed Test* or LAST) was piloted for validity, reliability, and practicality since, the choice for suitable soccer-specific anaerobic capacity tests were inadequate. It was found that two familiarisation sessions are necessary to reduce systematic bias markedly and habituate players with procedures of the LAST. The total measurement error (ratio of Limits of Agreement) of the LAST was 2.5% (± 18 m), and peak blood lactate values produced were 17.6 $mmol.l^{-1}$, which were greater than the 14.7 $mmol.l^{-1}$ criteria set for maximal anaerobic effort before the pilot study. The test set-up and administration proved to be practical, facilitating large numbers of subjects to be evaluated relatively quickly (< 20 min). Therefore, the LAST was included in the soccer-specific battery of field tests, which then provided a comprehensive analysis of the separate components soccer performance.

The available facility to conduct this investigation was the soccer-field at Al-Ahli Sports Club Doha, Qatar and therefore, further methodological investigations were necessary; temperatures within Qatar can vary during different times of the season, and at times are quite severe with respect to heat and humidity. The purpose of Study-2 was to examine how robust the discrete soccer-specific field tests were which, would be used during the intervention of Ramadan, using a repeated measures counter-balanced design of indoor and outdoor conditions. It was found that during the Yo-Yo Intermittent Recovery Test (YYIRT) (Krustrup *et al.,* 2003) outdoor assessment maximal performance was reduced by 19% in contrast to the YYIRT conducted indoors, despite the subjects attaining similar maximal heart rates. Consequently, the YYIRT to volitional exhaustion was excluded from the battery of tests to be used during the intervention of Ramadan; all other soccer-specific field tests were found to be robust for use in the heat.

The aim of Study-3 was a qualitative investigation to observe current soccer-practice and related factors surrounding training; this brief included bedtime, wake-up time, sleep duration, environmental conditions, pre-training dehydration, body fluids lost during training, body-core temperature, and relative training intensity. During Ramadan it was found that bedtime and wake-up time were significantly delayed and sleep duration lengthened compared to normal. Post-Ramadan was found to be akin to eastward time travel with advancement in bedtime, wake-up and return to normal sleep duration. Dehydration was significantly greater pre-training during Ramadan in comparison to non-Ramadan training weeks, and body fluid loss during training in both Ramadan and non-Ramadan periods was considerable. Relative training workload was also quantified during this time and highlighted important practical problems.

In Study-4 the consequences of the lifestyle changes of Ramadan on the discrete soccer-specific performance components were investigated. Key findings from this study were a significant reduction in aerobic power during Ramadan and a subsequent improvement post-Ramadan; these fluctuations were associated with the significant changes of pre-training dehydration during Ramadan. Sub-maximal aerobic performance was also affected by dehydration, causing $HR\%_{max}$ to rise and fall surrounding the Ramadan period. The anaerobic capacity was another fitness component that was influenced during Ramadan and this type of high-intensity activity was found to be not very well tolerated by some fasting players. Furthermore, improvements in vertical power measures were also noted during Ramadan, associated with dehydration.

The collective findings from this investigation have provided novel data on Islamic soccer players surrounding Ramadan. In order to further the understanding of the lifestyle changes connected with Ramadan the theoretical issues have been approached, with a schematic circadian model for professional soccer players. Practical applications of this model may be presented to help soccer coaches to address the stress surrounding Ramadan in a systematic manner, regarding the planning of training workloads around the additional lifestyle stresses that accompany the religious intervention of the holy month.

Acknowledgements

Firstly I would like to thank His Highness Sheikh Mohammed bin Khalifa Al-Thani (Royal family of Qatar) for allowing me to pursue my passion in soccer and complete my PhD thesis and activity within professional soccer in Qatar, whilst in his service.

I would like to express a massive thanks to Jose Robles (Junior) *Ziza* (Assistant and Head coach Al-Ahli 2003-2007), for his assistance at Al-Ahli Sports Club Doha; without his help this investigation would not have been possible! Ziza is from a legendary Brazilian soccer family, who have represented Brazil at World Cup level. Furthermore, Ziza himself was Brazilian player of the year 1975-76 and it is a great honour to know, have worked with, and have as a friend!

In the season prior to this investigation, familiarisation of the players and coaching staff regarding training workload quantification via heart rate monitors and testing procedures was undertaken. During this time I am grateful for the cooperation of another legendary and high profile Brazilian manager, Oswaldo de Oliveria (winner of the FIFA 1999 World Club Championship with Corinthians).

Also, from my time in Doha, I am thankful for the assistance from Michel Decastel (Switzerland) then head coach of Al-Ahli. Michel has been a head coach in his native homeland with FC Sion, and was also league champion in Tunisia with Club Sportif Sfaxien Tunisia, where he is currently based for his second spell.

I would like to express my gratitude to the students and P.E. Staff at Doha college (Qatar). The Physical Training Instructors of the British Armed forces and soldiers who participated in the pilot study. The professional players of Al-ahli (Qatar) and medical staff at Al-Ahli Sports Club, my thanks for all the hard work and effort throughout the respective studies; it was tough watching you!

I am extremely fortunate to have the *godfather* and a legendary figure of science and soccer as my supervisor Professor Thomas Reilly, whose words of wisdom, support, and guidance have been greatly appreciated. Furthermore, I would also like to acknowledge my thanks to Dr. Barry Drust another leading scientist within the soccer domain for his balancing and objective input.

A big thanks to the best mum in the universe, whose constant support and positive outlook throughout my playing and coaching career in soccer have been greatly valued!

I am also lucky to have one of my best friends as my brother and along with my sisters have provided equally positive encouragement, and a sounding board for frustrating times, of which there have been a few. I would like to thank my wife Tracey, who followed me to Qatar and backs me in all endeavours and is a great mother to our precious boy Josef "*the champ*".

TABLE OF CONTENTS.

Page

Chapter 2 Review of the literature.

Chapter 4 Study-2 The influence of environmental changes on a battery of soccer-specific field tests.

Chapter 5 Study 3 A qualitative analysis of lifestyle change and soccer training during and after the holy month of Ramadan.

Chapter 6 Study 4: The effects of Ramadan on a soccer-specific field test battery.

Chapter 7 Synthesis of findings

List of Figures

List of Figures

Page

List of Tables

Chapter 1

"Some people think football is a matter of life or death.
I can assure them, it's much more serious than that."

Bill Shankly, Liverpool F.C.(1959-74)

1.0 Introduction

Qatar is a Muslim country, and so in addition to around 1 billion other Muslims globally, naturally respects and adheres to one of the main pillars of Islam, the *holy month of Ramadan.* The religious festival of Ramadan takes place every year during the 9th lunar month and involves 4 weeks of intermittent fasting in which no food or water is permitted to pass through the lips between dawn and sunset. Nevertheless, professional Islamic football (soccer) players must still train and compete whilst fasting. Today there is a lack of research on the effects of the lifestyle intervention of intermittent fasting on training as well as performance in Muslim professional soccer players. Whilst there are Muslims playing professional soccer outside Islamic countries, their numbers have not been calculated in any source of literature.

The lunar year consists of approximately 354 days, and so Ramadan advances each solar year by 10/11 days. Therefore, it is possible that Ramadan can occur during different times of the Gregorian calendar year. The advancement of Ramadan each consecutive year can have a particular significance regarding preparation and participation of world competitions at elite level. The London Olympics 2012 are due to commence between 27th of July and 12th of August. Yet, during that year Ramadan is predicted to occur around the 21st July to the 21st of August. In addition to the Olympic soccer tournament, World Cup qualifications and Asian Champions league have the potential to schedule important games during the Islamic holy month (Robinson, 1991; Fazel, 1998; Burden, 2001; www.GamesBids.com, 2007). Within Ramadan certain individuals may experience muscle and psychomotor performance impairment, a negative energy balance, dehydration, premature fatigue, hunger, mood disturbance, and a reduced ability to concentrate; Muslim players face the daily challenge of consuming sufficient food and water to attain a nutritional equilibrium in a reduced period of time during darkness (Angel *et al.,* 1975; Husain *et al.,* 1987; Hallak and Nomani, 1988).

As well as the time of year of Ramadan, a further consideration is that Qatar is located in the Arabian Gulf, which is notorious for an environment that is hot and humid. The simultaneous combination of exercise, dehydration and heat stress inflicts arguably the most severe physiological challenge for an individual other than disease or serious loss of blood (Murray, 1998). So the additional stress from environmental factors whilst Islamic soccer players are fasting intermittently during Ramadan provides further concern for Qatari professional soccer players and coaches.

Experienced soccer coaches working Qatar, report that training and soccer match-play performances are inhibited both during and shortly after Ramadan. In order to investigate the effects of intermittent fasting on professional Qatari soccer players, a test battery applicable to soccer is needed. Analysis in the field provides high ecological validity as well as being of direct value to practitioners (Thomas and Nelson, 1996; Reilly and Williams, 2003; Svensson and Drust, 2005). Despite many suitable soccer-specific field tests in almost all the relevant components of soccer performance, there is no current consensus within the international (FIFA, UEFA, WCSF) or domestic (national soccer associations/federations) science and football domain, regarding a proposed model for a *gold standard battery of soccer specific-field tests and guidelines* for the fitness coach/sports scientist to follow in the professional world of soccer.

Therefore, prior to addressing the research problem, an extensive battery of field-tests based around the soccer-testing model (Ekblom, 1986) and discrete fitness components (Bangsbo, 2003) was assembled. However, the menu of anaerobic capacity tests suitable for soccer players was inadequate (Bangsbo, 1997; Hoff and Helgeurd, 2004). The anaerobic capacity of a player is an important aspect of performing and sustaining repeated high-intensity activities during match play, which are crucial to success in the modern game (Reilly and Williams, 2003; Mohr *et al.*, 2003). Therefore, it was logical that a soccer-specific anaerobic capacity field-test be included within the test battery, and so the *Liverpool Anaerobic Speed Test* or LAST was piloted in Study-1, for reliability, validity and practicality. Furthermore, the location of administration of the test battery was the grass-soccer field at Al-Ahli Sports Club (Doha, Qatar) located outdoors.

Consequently, an additional methodological study was necessary to investigate how robust the discrete soccer-specific field tests were that might be used for the main focus of this thesis in Study-4. There is a shortage of research into soccer field test performance in various hot and humid conditions in comparison to ambient temperatures.

Islamic societies reverse their circadian routine of eating and drinking and disrupt their sleep-wakefulness cycle during Ramadan. Many Islamic Soccer federations and coaches alter their training and competition match times to late evening (20:30-22:30 hours) to accommodate these changes. Thus, the opportunity to investigate a unique situation is available. There is a lack of studies associated with circadian rhythms during Ramadan. So far it has been suggested to be a hybrid of ageing, jet-lag, and shift-work models (Reilly and Waterhouse, 2007). Managing elite players' training and fixture schedule requires a fine balance between daily training load, total life stress and their capability to recover from such stressors. Monitoring these factors has become an essential part of most professional coaching regimens, and facilities a retrospective analysis that furthers understanding on lifestyle, training interventions and performance (Rosen *et al.,* 2001; Smith, 2003). The information gathered in the qualitative observational Study-3, and the discrete soccer-fitness component variations surrounding Ramadan in Study-4 provide novel information regarding sleep-wake cycle changes, hydration status, soccer practice and changes in performance surrounding Ramadan. As a result, a schematic circadian model for Islamic soccer players has been proposed and subsequently practical guidelines for soccer coaches to assist with planning soccer weeks around Ramadan.

1.1 Problem statement

A key area of inquiry for Islamic professional football players is to investigate the effects of intermittent fasting during Ramadan on training and performance, conducted in a hot and humid environment.

1.2 Aims and objectives

The theoretical and practical aspects of science and soccer are combined in this thesis with particular focus on Islamic professional soccer players in Qatar. The overall aim was to investigate lifestyle changes, soccer training and discrete soccer fitness components surrounding 4 weeks of intermittent fasting during the holy month of Ramadan.

In constructing a soccer-specific battery of tests to meet this overall aim, it was clear that additional technical and methodological studies were necessary prior to the main investigation. Furthermore, a qualitative investigation was also required to provide greater understanding on lifestyle circadian adjustments, environmental factors, and soccer practice. These preliminary studies helped to address the main aim and research question of the investigation systematically, and examine *the influence of the lifestyle changes around Ramadan on the discrete soccer fitness components.*

1.2.1 Study 1: Validity and reliability of LAST (Liverpool Anaerobic Speed Test)

The purpose of this technical study is to pilot a soccer-specific anaerobic capacity field test (LAST) for validity, reliability, and practicality in order to complete a comprehensive soccer specific battery of tests. The LAST is designed to be user friendly for soccer coaches and players, via more meaningful results i.e. *Total Distance* covered in *metres* rather than $W.kg^{-1}$. Essentially, players with the greatest anaerobic capacity are able to cover more total distance from three 60-s time trials over a 25-m course involving a soccer-specific push pass to change direction. Each 60-s time trial was interspersed with 60-s passive rest and the criterion for standardisation of the test was for each 60-s time trial to be completed at an intensity that produced a heart rate peak between 90-95% HR_{max} which, was ascertained with heart rate monitors.

1.2.2. Study 2: The influence of the environment changes on a battery of soccer-specific field tests

The administration of the test battery to be employed in the main part of the thesis (Study-4), was conducted on the grass-soccer field of Al-Ahli (Doha). Therefore, the aim of this methodological study was to evaluate how robust the soccer-specific field tests were in different climatic conditions, for application in the heat.

1.2.3. Study 3: A qualitative analysis of daily soccer training and lifestyle changes during and after the holy month of Ramadan

The aims of the qualitative analysis of daily lifestyle changes associated with Ramadan as well as soccer practice were to further understanding and facilitate a retrospective analysis following study-4 of any key performance variations surrounding Ramadan. Particular focus was on the daily routine of the 4-week period during and after Ramadan with regards:

1. Daily adjustments in bedtime, wake-up and sleep duration;
2. Environmental conditions;
3. Hydration status pre-training and body fluid loss during training;
4. Core gut temperature during training;
5. Relative training intensity and volume of daily practice sessions.

1.2.4. Study 4: The effects of Ramadan on a soccer-specific field test battery

The fourth study and main focus of the thesis examined the degree to which discrete soccer fitness components are impaired surrounding Ramadan. Consequently, the third and fourth studies provided original data that helped to develop the schematic Ramadan model for Islamic soccer players, as well as practical guidelines for soccer coaches with regards planning of soccer practice and key interventions.

Chapter 2

Review of the Literature

2.0 Review of the literature

2.1 Introduction

Research involving Qatari professional soccer players is lacking thus, the aim of this literature review is firstly to provide an overview of the game of soccer, for a general idea of non-Ramadan physical stress on players. Training procedure is also briefly appraised to provide a general insight into the components of soccer fitness, conditioning drills as well as methods for quantification of workload of training, that are relevant to aspects of this investigation. The physiological consequences of training and playing in hot and humid conditions will also be reviewed; Qatari soccer players participate in their sport under some of the most extreme environmental surroundings worldwide.

Ramadan is a focal part of Islam that frequently occurs during the soccer season, involving dramatic lifestyle changes particularly the adherence to intermittent fasting. Consequences of the 4-week religious intervention of intermittent fasting will provide the main focus of this review. Finally, as no current gold standard battery of soccer-specific field tests has been established within professional soccer, an evaluation of possibilities for each discrete soccer-specific fitness component will be examined, with a rationale for the selection of each test.

2.2 Demands of the game of soccer

The volume of games within the Qatari league is ultimately determined by the success of team. The Qatari league involves 27 league games (1 game a week, 10 league clubs), two major cup competitions (Crown Prince and Emir cup), and the top teams also participate in the Asian Champions League. Research involving the Qatari national soccer league and training methods is lacking. Therefore, a generic review of the literature on soccer will be provided as background information and indication of the demands of the game and training.

Typically time-motion analysis studies have noted that top class professionals cover a total distance of around 10-13 km during a match (Rienzi *et al.,* 1998, Verheijen, 1998; Shephard, 1999; Mohr *et al.,* 2003). Distances vary between players and are determined by the position roles within the team, standard of player, opponent, tactics and environment.

It has been suggested that the typical intensity of a game is around 70-80% of $\dot{V}O_{2\,max}$, close to lactate threshold (80-90% HR $_{max}$) with peak values of 98% HR $_{max}$ (Hoff and Helgerud, 2004; Bangsbo *et al.,* 2006). The amount of time actually spent at this intensity is roughly 20 minutes, as players are either exercising above lactate threshold thereby accumulating lactate, or conversely activity is below oxidising the accumulated lactate in the blood (Chamari *et al.,* 2004). Aerobic energy production accounts for between 88-90% total energy expenditure during a match (Mayhew and Wenger, 1985: Bangsbo, 1994).

High-intensity efforts within a game must be also be emphasized, since players usually have to run at cruise speed (submaximal striding) or sprint every 30 seconds, and around every 90 seconds perform an all-out sprint. High-intensity running or sprinting accounts for about 15% of the total distance covered (Reilly, 2003). Players also require the ability to develop rapid power output in various match situations and a combination of activities such as short sprint, tackle, shot, jump and so on. A player can perform over 1000 changes in movement within a match, roughly 1 every 6 seconds (Reilly and Thomas, 1976). Elite professionals conduct between 150-250 short intense actions during match play (Mohr *et al.,* 2003); these anaerobic activities are widely accepted by coaches and investigators as imperative to winning the game (Verheijen, 1998). Such frequent random patterns of high-intensity activity mix together with longer periods of lower intensity actions such as, jogging, walking and static pauses provide the rationale for the classification of soccer as an intermittent high-intensity team game (Bangsbo, 1994; Shephard, 1999).

2.3 Training for soccer

In order to perform successfully within match-play, it is essential for soccer players to participate in specific related training, and so conditioning for soccer must incorporate the many different aspects of fitness associated with the demands of the game. Notational analysis (Studwick and Reilly, 2001; Mohr *et al.,* 2003) has highlighted the key characteristics of top class players and this essential information can be used as guidance for training programme objectives. Additionally, soccer conditioning as well as soccer testing can be further broken down into a number of fitness components based on the primary energy systems involved at that intensity (See Fig 1. Bangsbo, 1994).

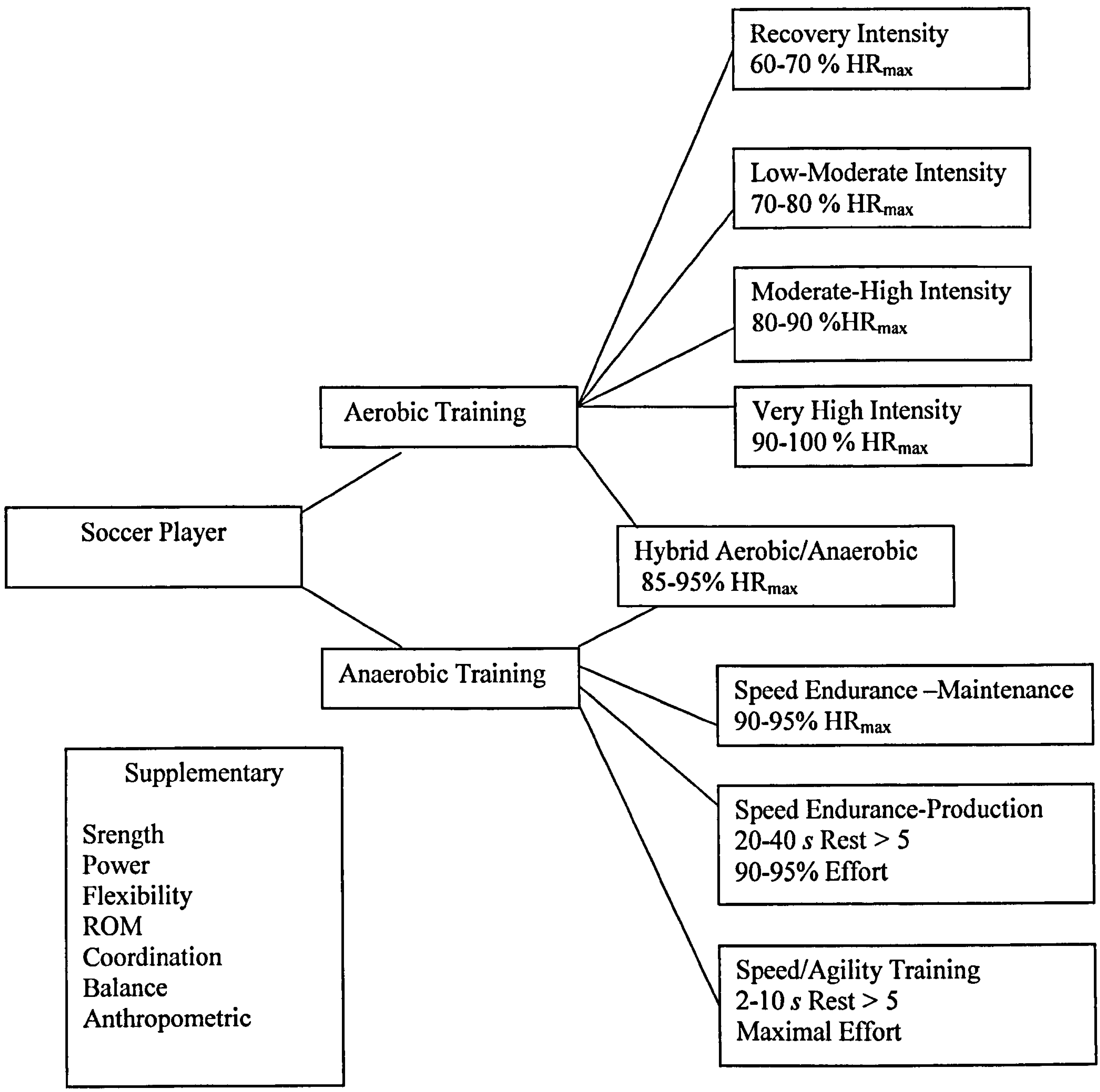


Figure 1. Fitness components of soccer

Modified from: Bangsbo (1994)

The fitness components of soccer players can be stimulated and overloaded with specific soccer conditioning drills (Helgerud *et al.*, 2001; Sassi *et al.*, 2004; Reilly and White, 2004). To obtain information about load within training, heart rate monitors are a valid measurement tool of intensity and have been used in numerous investigations (Foster *et al.*, 2001; Smith, 2003; Esposito *et al.*, 2004; Bangsbo *et al.*, 2006). Heart rate monitors help produce more effective practices and remove subjective evaluation of workload by coaches (MacLaren *et al.*, 1988; Van Gool *et al.*, 1988).

It is often necessary to modify soccer practice (Table I) during a session to achieve a training objective; heart rate monitors quantify changes and ensure that alterations made to the conditioning drill are applicable. Furthermore, workload completed during a training session can be quantified for each individual player using a modified training impulse (TRIMP value) (Table II); this simple calculation separates work intensities into heart rate zones and produces a TRIMP value based on the duration of exercise as minutes spent in each heart zone (1-5). The TRIMP method is a common system used by many practitioners within professional sport (Brandon, 2005).

Table I: Practical application of direct interventions on fitness components and soccer drills

Reference	Drill	Set up	Intervention	Outcome
Platt *et al.*, (2001)	3 v 3/ 4 v 4		Reduce number of players	↑ Number of Pass/Shot/Tackle ↑ Work Intensity
Aroso *et al.*, (2004)	4 v 4		Man to man marking	↑ Work Intensity
			Support players positioned on outside of pitch	↑ Work Intensity
Kelly (2005)	4 v 4	30 x 20 m	↑ Pitch 40 x 30 m	↓ Work Intensity ↑ Number of dribbles
Bangsbo (1994)	7 v 7	1/3 of Pitch	↑ Pitch Size ½	↑ Work Intensity
Bangsbo (1994)	7 v 7	½ Pitch	Maximum 2-touch	↑ Work Intensity (~10 beats.min^{-1})
Bangsbo (1994)	7 v 7	1/3 Pitch	Only score from behind	↑ Work Intensity
			↑ Pitch length	↑ Work Intensity
			All players over ½ way to score	↑ Work Intensity
Sassi *et al.*, (2004)	8 v 8		Stress Pressing	↑ Work Intensity
	4 v 4		No Goalkeeper	↑ Work Intensity
Verheijen (2003)	11 v 11	Full Pitch	Overlap After Pass	↑ Work Intensity

Table II: Example of modified TRIMP value table.

Heart rate zone	X	exercise duration (min)	=	Modified TRIMP Value
90-100% = 5	x	10 min	=	50
80-90% = 4	x	10 min	=	40
70-80% = 3	x	10 min	=	30
60-70% = 2	x	10 min	=	20
50-60% = 1	x	10 min	=	10

2.4 Summary

The generic intensity of soccer match-play has been highlighted within this section to provide a brief background to the reader regarding the demands of soccer; there is a lack of specific notational analysis research on the Qatari professional league. The game of soccer is classified as a high-intensity intermittent game involving random unpredictable movements.

The majority of coaches in Qatar still employ a subjective evaluation (craft knowledge) of workload and relative intensities of soccer practice. Consequently, training workloads undertaken by Qatari professional players at various stages of the season, particularly Ramadan, are unclear. This aspect of the review briefly highlighted the training process including the discrete soccer fitness components, and soccer conditioning drills, the consequences of alterations to soccer practice with regard to intensity, and procedures for quantifying training intensity and duration via Modified Trimp values.

3.0 Environment

This section will focus on the physiological consequences of exercise in the heat and provide an indication of the additional stress for the Qatari soccer players in training and games from the environmental surroundings during most of the season. The simultaneous combination of training, heat stress, and dehydration inflicts a formidable challenge to the body. A player must control the generation of a high turnover of metabolic heat in order to sustain activity, adjust bodily functions for fluid loss and simultaneously cope with possible heat gain from the environment (Murray, 1998; Maughan and Shirreffs, 2004). Highly conditioned soccer players are more capable of dealing with thermal stress; relative exercise intensity (% $\dot{V}O_{2max}$) rather than the absolute workload will determine the performance outcome of an exercise task. The cardiovascular system of elite players is able to cope better with the dual roles of thermoregulation and exercise, in comparison to players of a lower level (Bangsbo, 2003). Another factor to note is that the majority of physiological adaptations of mechanisms to deal with heat stress occur within 7-14 days; therefore, there is possibly no advantage for players living for prolonged periods in a hot climate (Montain *et al.*, 1996). Furthermore, players who reside in a hot country may experience chronic hypohydration due to daily insufficient replacement of fluid (Maughan and Shirreffs, 2004).

3. 1 Heat stress

Roughly only 20-25% of energy generated is directed to facilitate exercise. The other 75-80% is dissipated as heat within active muscle and consequently t body temperature rises during physical activity. The body has innate mechanisms for thermal equilibrium and preventing overheating; a heat balance equation below describes this process (Nadel, 1988; Reilly and Williams, 2003):

$$M - S = E \pm C \pm R \pm K$$

Metabolic Rate = M

Heat Storage = S

Evaporation = E

Convention = C

Radiation = R

Conduction = K

Body temperature is regulated around 37°C, but this value can vary depending on the measurement site (Shipp *et al.,* 2004). Body temperature is typically evaluated in the rectum and rectal temperature is the traditional gold standard measurement site; however this is not a suitable measurement site during situations where temperature changes quickly. Furthermore, the rectal probe must be inserted to a depth of 10 to 12cm (Waterhouse *et al.,* 2005) for reliable data and maintaining this depth throughout the duration of soccer practice may be problematic, as well as causing discomfort. The oesophageal method of core temperature is a highly accurate mode of measurement of core temperature, but the invasive nature of the protocol is likely to reduce the potential number of volunteers within a professional soccer environment. Tympanic body temperature measurement can provide a less invasive alternative to both rectal and oesophageal sites, but care is needed to avoid damage to the ear membrane. Additionally, insulation of the ear is necessary as environmental factors may distort the reliability of the values. The axilla and groin measurement sites of core temperature are two of the least invasive means of body temperature evaluation; however they have both been found to provide a poor indication of thermal stress (Reilly and Waterhouse, 2005).

Disposable stomach pills and a data logger placed in a belt around the subject's waist have been used to measure core temperature. Edwards and co-workers (2002) found the gut thermistor pill yielded body temperatures similar to rectal temperature values, although measurements taken by the thermistor pill were consistently 0.2°C higher in contrast to values obtained by the rectal probe. Furthermore, careful timing of the ingestion of the stomach pill prior to analysis is crucial, since the temperature of food and drink may influence the reliability of the data.

Skin temperature is usually around 33 °C; it is less than core temperature with a concurrent gradient from skin to air that facilitates heat loss to the surroundings via convection and radiation (Waterhouse *et al.,* 2005). Hot, humid, sunny and dry climates can create an environmental condition that exceeds skin temperature and consequently, the key thermal balance mechanisms are hindered and heat transference is retarded.

The degree of heat stress and relative intensity of exercise will determine core temperature (Rowell, 1983). The hypothalamus is the main coordinating centre for the various processes of temperature control, and makes thermoregulatory adjustments to deviations from the temperature norm. Heat-regulating mechanisms are activated through an internal feedback system (Figure 2), initiated from thermal receptors located in the skin as well as by direct stimulation of the hypothalamus from changes in blood temperature. The reaction from the hypothalamus is to stimulate sympathetic nerves that activate sweat glands of the skin to produce sweat; as the water of sweat evaporates from the surface of the skin the body is cooled (Roitman *et al.,* 1998). The physiological response to exercise in the heat has several common characteristics (Table III) that are at some stage related to body fluid loss and dehydration (Armstrong and Maresh, 1991).

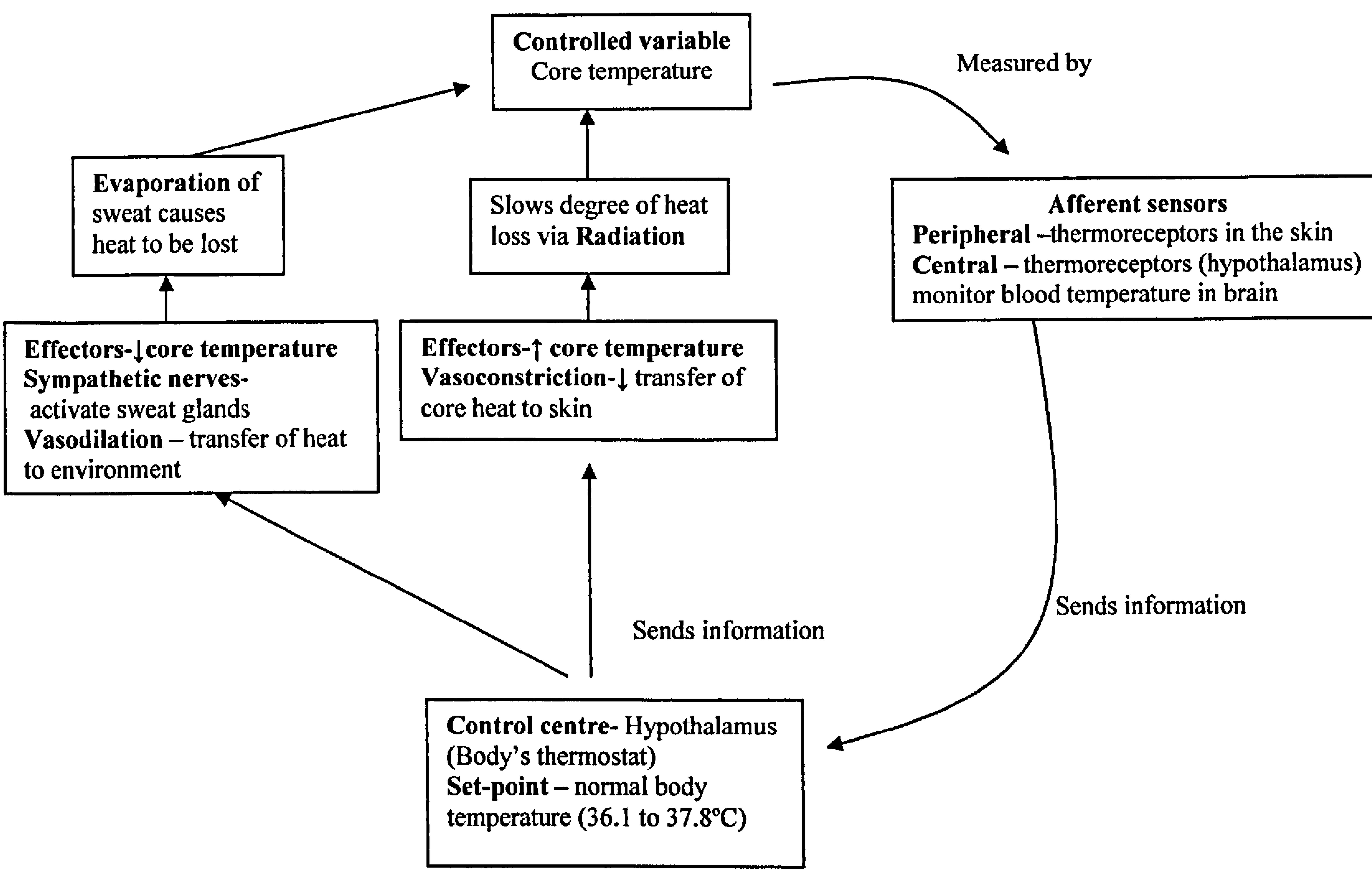


Figure 2. Feedback loop for temperature regulation.

Modified from: Waterhouse (2004)

Table III: Acute effects of a hot environment on physiological responses.

↑ Heart Rate (submax)
↑ Tcore (submax)
↑ Catecholamines (submax)
↑ Glycogen Utilization (submax)
↑ Lactate Production (submax)
↑ Ventilation
↑ RPE
↑ Perception of Effort
↓ Cerebral Blood Flow

(Armstrong and Maresh, 1991; Rowell, 1983)

3.2 Dehydration

If dehydration is present, any acclimatization and improved ability to tolerate and cope with heat stress are lost (see Table IV). There seems to be no physiological adaptation to dehydration. Restricted fluid intake can be dangerous (Sawka and Pandolf, 1990) and it has been recommended that athletes do not restrict body mass losses associated with fluid losses to more than 1-2% body mass pre-activity (Coyle, 2004). Prior dehydration will impair performance particularly during high-intensity prolonged exercise (Maughan and Shirreffs, 2004).

Table IV: Major acclimatisation effects of heat exposure.

Acclimatisation Response	*Effect*
Improved cutaneous blood flow	Transports metabolic heat from deep tissues to the outer body and skin more efficiently.
Effective distribution of cardiac output ($\dot{Q}$)	Appropriate circulation to skin and muscles to meet demands of metabolism and thermoregulation; greater stability of blood pressure during exercise.
Lowered threshold for start of Sweating	Evaporative cooling begins early during exercise.
More effective distribution of sweat over skin surface.	Optimum use of effective surface for evaporative cooling.
Increased sweat output.	Maximises evaporative cooling.
Lowered salt concentration of sweat	Dilute sweat preserves electrolytes in extracellular fluid.
Lower skin and core temperature and heart rate for standard exercise.	Facilitates greater portion of $\dot{Q}$ for distribution to active muscles.
Less reliance on CHO catabolism during exercise	CHO sparing effect.

(*Adapted from*: Montain, 1996)

CHO = carbohydrate

The impact of hypohydration on intermittent performance has not been well studied, and there is a particular dearth of information regarding chronic dehydration. It is not clear whether or how acute hydration status influences strength, power, and high-intensity endurance activities lasting between 30 s and 120 s (Judelson *et al.,* 2007). However, acute hypohydration during prolonged continuous exercise events has been found to hinder performance (Burke and Hawley, 1997).

With regards training, Yeargin and co-workers (2006) found that American footballers lost an average 1.39 kg body mass (1.2%) from pre-practice to post-practice during a pre-season practice. However, Yeagin *et al.* (2006) did not take into consideration the effects of chronic hypohydration and their investigation was only over 8 days of practice. The problem with acute hydration studies is that the data produced provide only a partial snapshot of training intensities, conditions, and effects. Godek and co-workers (2005) investigated two days of pre-season (4^{th} and 8^{th} day) and found that American footballers' daily sweat losses were on average 9.4 litres from two training sessions per day. The observations of Yeagin *et al.,* (2006) and Godek *et al.,* (2005) provide a wide range of values with regards body fluid loss during a few days of training within pre-season. In contrast to evaluating hydration status on sporadic days or weeks of a phase of training, a more objective approach would be to report the hydration changes during a whole phase or block of training for example, all the weeks of the pre-season period.

The negative effects of hypohydration on performance are amplified when exercise is performed in the heat compared with the cold (Coyle, 2004). Soccer players have been known to lose over 3000 ml of fluids during a match in hot and humid surroundings (Table V). However, studies that included rehydration strategies have found hypohydration to be not so dramatic (Leatt, 1986; Kirkendall, 1983; Broad *et al.,* 1996). The more recent findings are an indication of greater awareness in soccer clubs and successful rehydration intervention.

Table V: Fluid balance measurements in elite intermittent sport.

Reference	Sport	n	Temp (°C)	Hum (%)	Sweat Loss (Total-ml)	Sweat Loss ($ml.h^{-1}$)	Fluid intake (Total ml)	Fluid intake ($ml.h^{-1}$)	Hypohydration (% /kg Body Mass)
Mustafa & Mohamed (1979)	Soccer	8 M	33	40	2089 ±637	-	657 ±328	-	1.4 kg
		8 M	26	78	2546 ±750	-	242 ±930	-	2.3 kg
		8 M	13	7	846 ±162	-	-	-	0.8 kg
Kirkendall (1983)	Soccer	-M	19	55	1310		1135		0.5%BM
Bangsbo (2003) Mexico World Cup 1986	Soccer	-	-	-	2500±200				2.5-4.5kg
Leatt (1986)	Soccer	7 M			2000		1000		1.0 kg
Pyke & Hahn (1980)	Aus Rules	8 M	27	52	3190	180	740	410	3.0%BM
	Foot	6 M	38	25	3630	210	1500	870	2.7%BM
Broad et al. (1996)	Soccer	30 F	30	35	1160±430	815±245	570 ±290	395 ±155	0.9±0.5%BM
	Soccer	10 F	26	78	1505±435	760±220	810 ±310	410 ±155	1.2±0.9%BM
Junior Elite Summer Training	Soccer	80 M	25	41	1555±510	985±320	670 ±425	430 ±310	1.2±0.7%BM
Junior Elite Winter Training	Soccer	46 M	9	61	1095±425	745±260	435 ±350	310 ±255	0.8±0.5%BM
Junior Elite Summer Match	Soccer	46 M	25	41	1935±620	1210±330	825 ±525	515 ±335	1.4±0.9%BM
Junior Elite Winter Match	Soccer	8 M	10	56	1585±585	1025±265	530 ±235	360 ±195	1.4±0.7%BM

(*Adapted from:* Buke and Hawley, 1997; Bangsbo, 2003)

The debilitative effects of the dehydration can be attenuated to some extent through rehydration strategies before, during and after activity (McGregor *et al.,* 1999a; Maughan and Shirreffs, 2004). Therefore, it is also important to monitor rehydration and individual consumption during training as well as games. However, there are internal and external factors that interact as well as supersede rehydration strategies (See Table VI) within soccer. At the time of sensations of thirst, there is already an approximate 1% reduction in body fluids. This phenomenon is the result of change in cellular osmolality with accompanying dryness of the mucous membrane in mouth and throat (Maughan and Shirreffs, 2004).

Table VI: Factors that influence fluid intake.

- Religion – Ramadan
- Sweat loss awareness/education players/coaches
- Availability of fluid at training –pitch side/dressing room
- Opportunity to drink-breaks in training/games
- Palatability of fluids-personal tastes need to be accommodated
- Gastrointestinal comfort – during training an playing
- Osmolality of fluids – Hypotonic: Isotonic: Hypertonic:
- Temperature of fluids – cold (0-5°C) and cool (15°C) preferable.
- Fear of ↑ in body weight –particularly squad players tournaments

(Boulze *et al.,* 1983; Szlyk *et al.,* 1990; Burke and Hawley, 1997)

3.3 Summary

Following on from the demands of the game, this environmental section has highlighted extra physiological challenges from heat facing the Qatari professional player that are not experienced by professional soccer players exercising in more temperate climates. The key physiological concerns from activity in the heat are centred around the rise in core temperature. Consequently, there is an increase in body fluid loss, sub-maximal heart rating, glycogen utilisation, sub-maximal lactate production, rate of perceived exertion. Dehydration results from the body's attempts to reduce core temperature, which inversely leads to a further rise in core temperature during sustained activity.

There is no physical adaptation to hypovolaemia, thus acclimatisation mechanisms are reduced once dehydration is present. Evidence has shown that soccer teams who do not have adequate rehydration strategies in place can lose a considerable amount of body fluids during games. Several factors were highlighted associated with rehydration strategies of players. Therefore, the addition of intermittent fasting during Ramadan for the Qatari player to the physiological stress from the demands of soccer played in an adverse environment provides a unique opportunity to investigate soccer players under some of the most challenging circumstances within the game!

4.0 Ramadan

The main pillars of Islam are Ramadan, statement of faith, prayers 5 times a day, charity for the poor, pilgrimage to Mecca (Hajj) and the oneness of god. The holy month of Ramadan takes place each year during the 9th lunar month. Ramadan is a period regarded as one of discipline, understanding and goodwill, with 4 weeks of intermittent fasting being compulsory within all the healthy Muslims. The ethos behind fasting is for spiritual purification, act of worship, improvement of health, self-control, avoidance of sin, safeguard against demonic influences and to ensure passage into the afterlife. The Koran permits several exemptions from fasting during Ramadan, which include illness, pregnancy, and Muslims who must travel. During each day of Ramadan between dawn and sunset (daylight) the main focus is nutritional abstinence; no food or drink is passed through the lips and consumed (Fazel, 1998; Roky *et al.,* 2001). Upon sunset the first main meal that breaks the fast is known as *iftar* and usually contains large quantities of carbohydrate-rich foods, traditionally dates. The final meal before the start of fast is known as *suhur* and usually takes place at very early hours of the morning to allow for morning prayers *fajr* and preparation of the day ahead (Robinson, 1991; Malik and co-workers, 1996).

The intermittent fast will vary in duration depending on geographical location, time of year, and may last up to 18 hours. The lunar year consists of approximately 354 days, about 10-11 days less than a solar year. So although Islamic holidays are celebrated on fixed dates, they usually shift approximately 10-11 days earlier with each successive solar year as per Gregorian calendar year. Therefore, it is possible that Ramadan can occur during different seasons of the year with obvious advantages/disadvantages during winter and summer months (Fazel, 1998; Burden, 2001).

4.1 Circadian variation

As Islamic societies reverse their daily routine of eating and drinking during Ramadan, they further disrupt their nocturnal sleep-wake cycle. Many coaches/athletes and Islamic soccer federations alter their training and competition match times to late evening (between 20:30 to 22:30 hours) to accommodate these changes. However, this would not be the case for those practicing the Ramadan fast in non-Muslim countries around the globe, since they must still adhere to their host country's way of life.

Therefore, the circadian rhythm adjustments of Muslims during Ramadan around the globe will vary. There is a lack of studies associated with circadian variation during Ramadan with exact responses unclear; so far it has been reported to be a hybrid between ageing, jet-lag, and shift-work models (Reilly and Waterhouse, 2007). Furthermore, it is likely that several Ramadan models are necessary, to accommodate the different lifestyle situations facing Muslims worldwide determined by the place of residence and employment requirements. The purpose of this investigation is to concentrate on Islamic soccer players of Qatar.

It is likely there are several coexisting body clocks within the human body that control a number of circadian rhythms. The suprachiasmatic nuclei (SCN) located in the anterior hypothalamus houses the master clock, which regulates circadian rhythms in mammals. Furthermore, circadian oscillators have been found in peripheral tissues including the cardiovascular system, liver, intestine, and retina (Curtis and Fitzgerald, 2006; Froy and Miskin, 2007; Reilly *et al.,* 2007). The most important rhythms regarding sports performance are associated with the acrophase of body temperature and the sleep-wake cycle. The key circadian rhythm connected with habitual activity is the sleep-wake cycle, which is harmonised with the natural occurrence of daylight and darkness (Reilly, 2003). The hypothalamus contains suprachiasmatic nuclei cells (SCN), which have melatonin receptors, and is the control centre for the body clock. Neural pathways (retinohypothalamic tract) link the SCN with the eyes and receive input via the pineal gland located in the brain, which secretes melatonin. The 24-hour day and night rhythm is synchronised by melatonin which is stimulated by darkness and inhibited by bright light (Tortora and Grabowski, 1996).

The explanation of the need for sleep is still not clear, but the most likely theory suggests that sleep is required for the restoration of body tissues and specific nerve cells, particularly associated with the brain. Nevertheless, the necessity for sleep becomes apparent when sleep is compromised, or broken. It has been noted that many professional soccer players spend longer in bed than in comparison to the general adult population (Reilly, 1995)

During Ramadan there have been recordings of reduced amplitudes as well as a delay in acrophase by 2-3 hours, and so phase shifts in circadian rhythms of body temperature. Consequently, there is a delay in bedtime, sleep latency and waking (Roky *et al.*, 2004; Bahammam, 2005). Changes in sleep measures have been associated with elevated rectal temperatures. Therefore, phase shifts in rhythms of body temperature may be even more profound in Qatari soccer players based on the timing of evening training in a hot and humid environment during Ramadan.

The sleep cycle may also be further disrupted to accommodate early morning prayer and food consumption. Chronic sleep disruption can hinder training and endurance performance (Martin, 1981; Reilly and Piercy, 1994). Furthermore, reductions in concentration have also been noted with sleep disturbances, and there may be health implications as sleep is linked with the immune system (Reilly, 1995). Zerguini and colleagues (2007) investigated two professional soccer teams during Ramadan in Algiers and found that 70% of players subjectively reported poor quality sleep, training and performance. Endurance performance is imperative to successful soccer performance and a reduction in this fitness component could be catastrophic, if competing against non-fasting players especially, as the professional players in this particular study had a relatively low $\dot{V}O_{2\max}$ baseline (52 $ml.kg^{-1}.min^{-1}$).

4.2 Psychomotor performance

Several research groups have looked at psychomotor performance during Ramadan (subjective alertness, mood, critical flicker fusion, and memory tests). They found that these components are impaired during intermittent fasting and suggested an association with concurrent calorie restriction and sleep length limitations during this time (Hakkou *et al.*, 1988; Ali and Amir, 1989; Pilcher and Huffcutt, 1996; Roky *et al.*, 2000).

Car accidents have been noted to increase (Shanks *et al.,* 1994) probably a result of hypoglycaemia symptoms, reduced concentration ability, alertness, increased aggressive moods contributing to more impatient drivers and bad decisions.

Afifi (1997) observed a lesser activity level, decreased motivation and again reduced concentration in more than 50% of 265 students during Ramadan. The aforementioned cognitive findings support the empirical evidence of Qatari soccer coaches, who report a considerable reduction in concentration during soccer practice in particular for tactical and technical elements of training and games.

4.3 Ramadan and the physiological effects

There is a shortage of investigations of the effects of Ramadan on performance (Roky *et al.,* 2000), and many of the studies have employed sedentary participants and so findings are limited regarding elite sports personnel. Much of the research surrounding Ramadan has mainly centred on plasma lipids, proteins, glucose, metabolic rate (Ch'ng *et al.,* 1989; El-Ati *et al.,* 1995; Iraki *et al.,* 1997) body mass, subcutaneous body fat, and cholesterol triglycerides (Angel and Schwartz, 1975; Fadail *et al.,* 1982; Hussain *et al.,* 1987; Frost *et al.,* 1987; Hallak and Normani, 1988; Malik *et al.,* 1996). The findings from the aforementioned work are mixed with conflicting observations and no clear trends. There appears to be a diverse individual response to the effects of intermittent fasting that is case specific. Therefore, it is erroneous to generalise the responses of Ramadan for all Muslims with regards fat, protein, glucose and metabolic related factors. Individual nutritional consumption varies from person to person during the evening. Today more affluent populations have greater opportunity to consume larger quantities of high-density calorie foods such as cakes, chocolates, sweets, fast foods and so forth; these foods have become more available in contrast to previous years especially, in the Arabian Gulf. Hence, the type of food ingested and lifestyle followed will play an influential part in contrasting findings between investigations that have been conducted over the years.

4.4 Ramadan and dehydration

Probably the most consistent physiological observation amongst fasters throughout Ramadan is dehydration. During the early days of the intermittent fast, significant reductions in body weight have been noted (Angel *et al.,* 1975; Husain *et al.,* 1987; Hallak and Normani, 1988). It has been postulated that this weight loss is a result of dehydration. Water consumption has been seen to decrease, in association with significantly higher serum sodium, chloride, and protein values, when comparing pre-test and end of week 1 of Ramadan analysis (Sweileh *et al.,* 1992). Dietary records indicate that the return of water balance to pre-fasting levels during the final week of Ramadan, is from an increase in water consumption during the night or enhanced water retention by the kidneys. Other factors that would contribute to a rapid reduction in body fluids include an initiation of caloric restriction, whereby around 66% of weight loss is a result of the 3 to 4 grams of water released for every gram of glycogen that is metabolised (Van Itallie and Yang, 1977: Brownell *et al.,* 1987).

Ramadan and co-workers (1999) investigated physiological effects of Ramadan in sedentary and physically active Kuwaiti males, at consecutive points in time before, two weeks during and at the end of Ramadan. They also observed significant increases in dehydration via urine osmolality and sodium levels, plus a marked decrease in respiratory exchange ratio in both groups, as well as serum iron reductions in sedentary males. The elevation in urine osmolality is directly related to reduced water intake and simultaneous water loss through sweating. Since the renal response is operated by a negative feedback loop, a chain of events transpires. The renin-angiotensin mechanism leads to the production of the hormone angiotensin II that stimulates the release of antidiuretic hormone (ADH) from the posterior pituitary gland. The ADH promotes water conservation by the kidneys and so elevates blood volume. Additionally, angiotensin II acts on the adrenal cortex to secrete aldosterone which boosts retention of sodium and chlorine, as well as water. Also, the hypothalamus is stimulated to activate thirst sensations so that the individual consumes more water, but cannot during daylight as he or she is fasting.

Consequently, the increased volume of reabsorbed water in the blood produces a smaller quantity of higher concentrated urine. Subsequently, there is a significant rise in urine osmolality. The hypernatraemia is associated with elevated aldosterone levels and the subsequent reabsorbed sodium ions (Tortora and Grabowski, 1996). The lower respiratory exchange ratio was suggested to be a product of metabolic adaptations and increased lipid usage. Serum iron reductions may be a result of micronutrient deficiency during daylight abstinence of food and drink (Ramadan *et al.,* 1999). Dehydration is a physiological phenomenon caused by playing the game of soccer and severities of dehydration will vary according to the individual, environment and intensity of play (Shephard, 1999). It is clear Ramadan has the potential to amplify the debilitative effects of dehydration and glycogen depletion related fatigue in both training and competitive games; it appears players are highly likely to commence soccer practice or games in a dehydrated state during Ramadan.

4.5 Negative calorie balance and hypoglycaemia

Nutritional balance, estimated energy expenditure, and hypoglycaemia are not the focus of this investigation; although they are very important factors with regards Islamic soccer players, Ramadan, as well as exercise performance. Nevertheless, they are worthy of inclusion to provide a holistic overview of the consequences associated with intermittent fasting.

Hormones associated with energy balance include leptin and ghrelin. Leptin is a hormone that plays a key role in the regulation of energy intake, expenditure, and fat deposition. Circulating leptin levels inhibit the activity of neurons that contain neuropeptide-Y, and consequently stimulate a reduction in appetite and increase in metabolism. Obese people generally have unusually high circulating levels of leptin and are thought to be resistant to the effects of leptin, akin to the population who suffer from type-2 diabetes and insulin regulation (Considine *et al.,* 1996). Serum leptin levels have been reported to increase significantly in both obese and lean subjects throughout the Ramadan festival (Kassab *et al.,* 2003).

Furthermore, Bogdan and co-workers (2005) found a five and half-hour shift in peak and trough serum leptin levels during the 23rd day of Ramadan. In contrast, ghrelin is a hormone produced in the P/D1 cells lining the fundus of the stomach and stimulates appetite in response to hunger (Asakawa *et al.,* 2004). Plasma ghrelin levels are elevated during fasting and reduced following ingestion of glucose and lipid, but not protein (Nonogaki, 2007).
The hormones that control digestion include gastrin, secretin, and cholecystokinin. Gastrin stimulates the stomach to produce acid for dissolving foods, during fasting within Ramadan increased gastric acidity is common (Nomani *et al.,* 2005), but one month post-Ramadan gastric elevation has been reported to return to pre-Ramadan levels (Hakkou *et al.,* 1994). Secretin causes the pancreas to produce digestive juices that are rich in bicarbonate and the stomach to make pepsin, the enzyme involved in digestion of protein. Hakkou and co-workers (1994) also found pepsin levels to be elevated by 133% within the holy month and again significantly reduced after Ramadan. These gastric secretion modifications surrounding Ramadan were suggested by the investigators to be associated with disturbed digestion during the holy month.

Within Ramadan certain individuals may experience a negative energy balance (Angel *et al.,* 1975; Husain *et al.,* 1987; Hallak *et al.,* 1988; Reilly and Waterhouse, 2007). This factor is of particular significance with regards training and playing professional soccer. Participation in the game requires a nutritional equilibrium to meet the demands of training and playing soccer. The problems of chronic negative energy balance with regards soccer include the potential disturbance of homeostasis of hormonal, metabolic and immune functions. Insufficient calorie intake for soccer players has been and in some cases still is a widespread problem in professional soccer worldwide. Readers are referred to other sources (Bangsbo, 1994; Reilly 1997; Rico-Sanz *et al.,* 1998; Burke *et al.,* 2006) for recommendations on daily calorie intake and expenditure during intense soccer training. These investigators have illustrated the importance of a calorie balance regarding soccer players with particular reference to high carbohydrates to facilitate such high-intensity intermittent training.

With regard to the consequences of inadequate nutrition and match-play, readers are directed to the classic study of Saltin (1973). He studied the depletion of glycogen stores and the negative effects on distance covered and high-intensity actions with in a game. More recently Krustrup and co-workers (2003) investigated glycogen depletion in type I and type IIA muscle fibres and fatigue following games. The possibility of a negative calorie balance especially of carbohydrate foods during Ramadan is of concern for Islamic soccer players.

In conjunction with energy intake, energy expenditure should also be taken into consideration. A valid approach to estimating energy expenditure has been reported by Spurr and co-workers (1988), involving a VO_2-HR relationship conducted within a laboratory setting. Subsequently estimated calculations of energy expenditure in the field can then be made; this procedure has been employed by several investigators (Reilly and Thomas, 1979; Brutsaert *et al.,* 2000; Bangsbo *et al.,* 2006).

The effects of hypoglycaemia are important considerations during intermittent fasting; lapses in concentration, impaired decision-making, lack of motivation for maximal exercise, varied mood are all symptoms of hypoglycaemia that can manifest during Ramadan. Hypoglycaemia has also been associated with fatigue during long-term exercise and the capability of liver gluconeogenesis to sustain blood glucose levels when glycogen stores are low. The brain and central nervous systems rely on glucose for their metabolism (Fitts, 1994; Shanks *et al.,* 1994). Mohr and colleagues (2005) have observed that blood glucose concentration does not reach critical values during a soccer match. In contrast, Ekblom (1986) noted blood glucose concentrations in some players were lower than normal resting levels of 5.0 $mmol.l^{-1}$ following the end of Swedish first division game, values reaching 3.0 and 3.2 $mmol.1^{-1}$, respectively. Such blood glucose levels have been linked to nervousness and trembling, and levels below 3.0 $mmol.1^{-1}$with loss of consciousness. The contrasting findings may be indicative of the superior nutritional strategies currently employed in top class soccer pre-match meals including lower glycaemic index foods plus players drinking carbohydrate and electrolyte beverages during the warm-up, half time or at random stages of the game. Nevertheless, hypoglycaemia in Islamic soccer players during Ramadan is another area of needed research as the prevalence in players is unclear, but empirically has been reported on occasion.

4.6 Cardiovascular performance studies during Ramadan

The number of studies investigating the physiological responses during Ramadan is low and few have contained elite sports people, especially soccer players. There is a great need for this gap in research to be addressed and soon. The London Olympics 2012 is due to commence between 27th of July and 12th of August. During that year Ramadan is predicted to occur around the 21st July to the 21st of August, so there appears no avoidance of the collision of the games and Ramadan. It is anticipated that 3,000 Muslim competitors will be affected and as 11, 099 took part in Athens 2004, the number of Muslim participants is a considerable proportion (www.GamesBids.com, 2007).

Of the few studies of performance during Ramadan, Ramadan and Barac-Nieto (2000) noted heart rate responses to bouts of moderate intense sub-maximal exercise (70% $\dot{V}O_{2max}$) were significantly reduced by the end of Ramadan and stayed around the same level 4 weeks post-fasting. Conclusions from the study were that heart rate reduction was connected to hormonal changes associated with dehydration or fasting and abstention from negative inotropy.
Yet, hormonal changes with dehydration are mainly renal (rennin-angiotensin mechanism) and the endocrine system functions on a negative feedback loop, therefore any alterations during Ramadan are likely to be reversed upon the return back to euhydration post-Ramadan. Furthermore, dehydration is associated with cardiovascular drift, and an increase in heart rate, not decrease (Roitman, 1998), and substances that potentially affect the heart muscle and would have been withdrawn during fasting are most likely to be replaced following fasting. One such relevant substance would be cigarette smoke, which is prevalent in the Arabian Gulf. Since nicotine is a stimulant; it would have also induced positive inotropy, again causing heart rate to rise. A negative inotropy would be beta blocker drugs (Martin, 1998) thus, questioning the conclusions made by Ramadan and Barac-Nieto (2000).

Sweileh and co-workers (1992) also investigated physical activity during Ramadan and suggested that exercise economy, which was measured by $\dot{V}O_2$ in $ml.kg^{-1}.min^{-1}$ was not adversely affected by the Ramadan period. However, the submaximal exercise protocol employed was a standard walk on a treadmill at a 4% gradient at 4 $km.h^{-1}$ for a total of only 5 minutes.

Therefore, such a sweeping statement as, "*exercise economy is not affected during the 4 weeks of a Ramadan fast*" is possibly erroneous based on the evidence presented, since neither the intensity nor the duration replicates any known sport, recreational activity, or credible training programme and is merely at best, a sedentary walk. In order for the findings of Sweileh and co-workers (1992) to be meaningful to the recreational or sporting world, their exercise protocol used for the investigation should have been modified; the relative intensity of the exercise task for the subjects employed was equivalent to 65-69% of HR_{max}; this exercise intensity is more indicative of a recovery session (Bangsbo, 2003).

With regard to maximal oxygen uptake ($\dot{V}O_{2max}$), Sweileh and co-workers (1992) found a decrease in $\dot{V}O_{2max}$ between the pre-test and the first week of Ramadan. However, when the data were examined in $ml.kg^{-1}.min^{-1}$ in contrast to the original $l.min^{-1}$, there was little change in $\dot{V}O_{2max}$. The negative effects observed on absolute $\dot{V}O_{2max}$ from dehydration (-1.7% body weight) were counterbalanced when $\dot{V}O_{2max}$ was reported relative to body weight. This finding is similar to other investigations analysing heat stress and dehydration (Saltin, 1964). During the last week of Ramadan, absolute $\dot{V}O_{2max}$ was noted to increase back to pre-Ramadan values. However, relative $\dot{V}O_{2max}$ was enhanced to greater than pre-Ramadan values, this phenomenon can be explained in part by a return to hydration status as well as an improvement in the lean muscle tissue to fat ratio. During the aforementioned investigation by Sweileh and co-workers (1992) none of the subjects were involved in an exercise programme or increased their physical activity.

4.7 Summary

The dearth of research surrounding Ramadan may reflect the difficulty in recruiting or gaining access to subjects during the 4-week intermittent fast. With the impending collision of the 2012 Olympics during Ramadan as well as the current Islamic soccer teams involved in leagues and tournaments it is essential for soccer coaches and sports scientists to come together and work more closely to address potential performance problems linked with Ramadan.

The key detrimental consequences associated with the lifestyle changes during Ramadan are adjustment in sleep-wake cycle, dehydration and negative calorie balance. The effects of chronic dehydration and negative energy intake during Ramadan on soccer players engaged in full-time training and match fixtures are still not clear.

5.0 Soccer-specific battery of field tests

In order to investigate the effects of intermittent fasting on professional Qatari soccer players, a test battery of applicable soccer field tests is needed. Analysis in the field provides high ecological validity as well as being of direct value to practitioners (Thomas and Nelson, 1996; Reilly and Williams, 2003; Svensson and Drust, 2005). Despite many suitable soccer specific field tests in almost all the relevant components of soccer performance, there is no current consensus within the international (FIFA, UEFA, WCSF) or domestic (national soccer associations/federations) science and football domain, regarding a proposed model for a *gold standard battery of soccer specific field tests and guidelines* for the fitness coach/sports scientist to follow in the professional world of soccer. Current selections of soccer tests are determined by the individual philosophy of the soccer fitness coach/sports scientist. Consequently, there are many different methods and guidelines used for evaluation of similar fitness components (Erith, 2004). Furthermore, the complex natures of soccer, and the various fitness components involved in the demands of match-play, result in no single test being applicable to predict every aspect of physical ability involved in soccer; therefore, a widespread battery of fitness tests is required (Svensson and Drust, 2005).

5.1. Aerobic performance

Aerobic endurance is primarily determined by $\dot{V}O_{2\max}$, sub-maximal functional utilisation ($\%\dot{V}O_{2\max}$), and economy of exercise. Maximal oxygen uptake is an important factor that determines the upper limit of endurance performance. Yet, it is the ability to sustain activity at a high fractional $\%\dot{V}O_{2\max}$, and running economy that determine as well as separate, sub-maximal endurance performance between individuals.

For instance, two people with identical $\dot{V}O_{2max}$ levels may differ considerably in sub-maximal endurance performance, or a person's sub-maximal endurance capability may change in accordance with a training programme over time despite relatively little change in $\dot{V}O_{2max}$ (Coyle *et al.,* 1988; Bassett and Howley, 2000). Therefore, it is logical that separate maximal and sub-maximal aerobic performance tests are included to facilitate this and other investigations.

5.2 Aerobic $\dot{V}O_{2max}$ (Aerobic power)

Maximal aerobic power is the highest energy output that can be produced via the aerobic processes within the limitation of the working capability of the circulatory system (Astrand and Rodahl, 1986). It can be established through assessment of maximal oxygen uptake ($\dot{V}O_{2max}$), which is the greatest quantity of oxygen the body can utilise during exhaustive exercise whilst at sea level. Oxygen uptake $\dot{V}O_{2max}$ is the product of cardiac output ($\dot{Q}$) and arterio-venous oxygen difference. Resting oxygen uptake is estimated to be around 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$, and during maximal exercise values range between 40-80 $ml \cdot kg^{-1} \cdot min^{-1}$. Both aerobic and anaerobic pathways provide energy supply for a $\dot{V}O_{2max}$ performance. As the anaerobic capacity is limited, working at $\dot{V}O_{2max}$ can only be sustained for a very short period of time.

5.3 Aerobic power ($\dot{V}O_{2max}$) and soccer performance

Bangsbo and Lindquist (1992) have noted that the $\dot{V}O_{2max}$ test is not an accurate measure of sub-maximal soccer-specific endurance capacity. The objective of a maximal oxygen uptake evaluation of soccer players is to provide an indication of a player's upper limits and potential for endurance performance. This is useful information for coaches regarding players' optimum positional roles and tactics of the team plus, maximal heart rate can also be attained from the $\dot{V}O_{2max}$ test. Maximal heart rate is not influenced directly by training or indicative of fitness levels. The knowledge of a player's maximal heart rate is essential for the daily implementation of optimal training and recovery programmes (Smith, 2003).

Several investigators have observed a link between the characteristics of fitness within a game and $\dot{V}O_{2max}$. Smaros (1980) noted that players with a higher $\dot{V}O_{2max}$ participated in more decisive activities within a match, performed more sprints in comparison to those with a lower $\dot{V}O_{2max}$. Van Gool and co-workers (1988) found significant differences between playing position within a team and $\dot{V}O_{2max}$. Further, midfield players generally have significantly greater aerobic power values in comparison to the other positional roles (Reilly and Williams, 2003). A high rank order correlation between $\dot{V}O_{2max}$ and final position in the league has been found in both Hungarian players and Norwegian players (Apor, 1988; Wisloff *et al.,* 1998). The aforementioned findings demonstrate that elite level footballers generally possess a higher $\dot{V}O_{2max}$ in comparison to what is considered a lesser player, thereby covering more distance in a game and at greater intensities. The $\dot{V}O_{2max}$ values for top class soccer players is roughly between 55-70 ml.kg^{-1} min^{-1} (Shephard, 1999), Table III provides examples of different leagues to date, and possible field test options for aerobic power assessment are listed in Table IV.

Table VII. Maximal oxygen uptake of elite soccer players

Reference	(n)	Team/level	$\dot{V}O_{2max}$ (ml·kg^{-1}·min^{-1})
Europe			
Wisloff et al. (1998)	-	Norway –Champions	67.6 ± 4.0
Wisloff et al. (1998)	-	Norway –elite league	59.9 ± 4.1
Faina et al. (1988)	6	Italian Amateur	64.1 ± 7.2
Strudwick et al. (2002)	24	England-Premier league	59.4 ± 6.2
Edwards et al. (2003)	12	Professional British	63.3 ± 5.8
Urhausen et al. (1996)	-	German-Top level Players	59.5 ± 4.8
Casajus, (2001)	12	Spain – Division 1	66.4 ± 7.6
Rest of the World			
Al-Hazzaa et al. (2001)	23	Saudi –National Tea	58.0 ± 4.9
Aziz et al. (2000)	23	Singapore National Team	58.2 ± 3.7
Green (1992)	-	Australian National league	57.6 ± 3.5
Da Silva (1999)	27	Brazilian Professional	52.5 ± 7.49

Table VIII: Possible field test options for maximal oxygen uptake in soccer players.

Author	Test Name	Description
Leger & Boucher (1980)	University of Montreal track test	Continuous multistage maximal track test 166.7 m indoor track speed ↑ every 2 min until Vol Exh.
Cooper (1968)	Cooper 12 min run	Continuous self-paced run for 12 min
Bangsbo & Lindquist (1992)	Soccer-specific endurance test ($\dot{V}O_{2\max}$)	Intermittent 15 s high / 10 s low intensity 40 bouts – duration 16.5 min
Kemi et al. (2003)	Soccer-specific field test ($\dot{V}O_{2\max}$)	Multidirectional dribble track with ball 95% Max HR – maintain 3 min ↑ speed to Vol Exh. (test time approx. 6-8min)
Ramsbottom et al. (1988)	20-m Multistage Fitness Test (MSFT)	Continuous multistage shuttle test start 8 $km \cdot h^{-1}$ speed ↑ every 60 sec-Vol Exh.

Vol.Exh. = Volitional Exhaustion

5.4 Soccer-specific $\dot{V}O_{2\max}$ test

Widespread view is now that an inclined treadmill test (ITT) of $\dot{V}O_{2\max}$ is the most reliable *gold standard* method of assessment (Kemi *et al.*, 2003; Chamari and co-workers, 2003). The Multi-Stage Fitness Test (MSFT) (Ramsbottom *et al.*, 1988) is suitable for employment to estimate $\dot{V}O_{2\max}$ in a soccer-specific field test battery, as an independent cross validation (Aziz *et al.*, 2005) indicated a significant correlation between the ITT and MSFT measurements of aerobic power. The feedback from the MSFT is that it is user friendly and easily interpreted for players and coaches. In support of this selection, it has been found to be a valid field measurement of aerobic power and applicable mode of assessment with soccer players by several investigators (Leger and Gadoury, 1989; Ekblom, 1994, Verheijen, 1998, Reilly and Wells, 1999). The MSFT produces the necessary data for the practitioner estimating $\dot{V}O_{2\max}$ values and maximal heart rate.

5.5 Sub-maximal aerobic performance

Sub-maximal measurements of aerobic performance are more sensitive and reflective of transitional fitness capabilities of athletes. Further, sub-maximal aerobic performance is a more consistent and superior predictor of aerobic endurance performance in sports, than $\dot{V}O_{2max}$ (Ekblom, 1994; Bassett and Howley, 2000; Chamari *et al.*, 2003).

5.6 Sub-maximal aerobic soccer field test options

Numerous soccer-specific aerobic field tests exist (Bangsbo and Lindquist, 1992; Bangsbo, 1996; Rico-Sanz *et al.*, 1999; Kemi *et al.*, 2003; Limminink *et al.*, 2004). However, many of these intermittent soccer field tests require effort until volitional exhaustion, and do not produce a valid estimate of $\dot{V}O_{2max}$. Possible reasons for the failure of these intermittent tests to produce a valid measure of aerobic power are the higher velocities involved within these respective tests in comparison to continuous modes of aerobic power measurement also, the designs require players to sustain these speeds for longer durations that they are accustomed to during match-play (Mohr *et al.*, 2003).

Consequently, peripheral factors (metabolic, running economy) are more likely to limit intermittent soccer field tests to exhaustion rather than the central components (cardio-respiratory - heart, lungs, and blood) and the capability to transport oxygen to muscles; the central components are thought to limit $\dot{V}O_{2max}$ performance (Bassett and Howley, 2000). Blood lactate values taken from Tunisian international players using Bangsbo's Yo-Yo intermittent endurance test (1996) were noted at 14.84 $mmol \cdot l^{-1}$ (Chamari *et al.*, 2004). Additionally, during the reliability investigation of the Yo-Yo intermittent recovery test (YYIRT), Krustrup and co-workers (2003) observed blood lactate values of 10.1 ±0.6 $mmol.l^{-1}$, and considerable differences in performances of participants with similar $\dot{V}O_{2max}$ values.

Therefore, it is clear that the aforementioned aerobic tests are unsuitable for estimation of aerobic power, and when performed to volitional exhaustion they highly tax anaerobic energy systems, and so are likely to be too intense for a sub-maximal aerobic evaluation. Many of these aerobic tests mentioned are loosely classified as generic aerobic soccer tests based on their intermittent design. Perhaps, a better classification would be to categorize such high-intensity intermittent aerobic tests within the soccer-fitness component concept, as a *hybrid* of aerobic and anaerobic fitness (Figure 1), so coaches are aware of the physiological fitness components they are evaluating.

For the purpose of this investigation, the *hybrid aerobic/anaerobic* fitness component would be evaluated using the YYIRT (Krustrup *et al.,* 2003) within the soccer-specific battery of field tests; since it a sensitive measure of detecting changes in high-intensity intermittent performance. Furthermore high-intensity intermittent aerobic tests have been found to correlate positively with velocity at $\dot{V}O_{2max}$ ($_v\dot{V}O_{2max}$); typically, $_v\dot{V}O_{2max}$ is a point thought to lie between lactate threshold and velocity at the end of a $\dot{V}O_{2max}$ test (Anderson, 2000; Chamari *et al.,* 2004). Therefore, the hybrid aerobic/anaerobic fitness component could be a measure of exercise capability akin to $_v\dot{V}O_{2max}$ used in distance running for many years and has also been found to be an outstanding predictor of performance in contrast to $\dot{V}O_{2max}$ and has been employed to determine training programs for athletes (Billat and Koralsztein, 1996).

5.7 Sub-maximal aerobic soccer field test selection

Krustrup and co-workers (2003) found that during YYIRT level-1, heart rates at 6 and minutes were *sensitive* enough to detect differences in sub-maximal performance at different stages of the season. The heart rates were significantly lower by 9 ± 2 beats.min^{-1}during the season in comparison to pre-season measurements. During sub-maximal exercise greater aerobic conditioning results in relatively lower heart rates at similar work intensities, as well as quicker recovery and such indices are used to monitor cardio-respiratory fitness (Smith, 2003). The 6-minute sub-maximal modification has also been used by Mohr and co-workers (2003b).

The 9-min YYIRT modified version (Krustrup *et al.,* 2003) was selected for the specific battery of tests for the present studies of investigations blood lactate values taken at the 9 minute mark (1080 m) were around 4 mmol.l^{-1}, which is the criteria used for the gold standard lactate threshold laboratory test and so indicates that this intensity is applicable. Also, the velocity of the modified YYIRT is appropriate for soccer players, the YYIRT finishes at a top speed of 15.8 km.h^{-1} and moderate running velocity within match-play has been classified as 15 km·h^{-1} (Mohr *et al.,* 2003). The 9-min modified YYIET does not require maximal effort and so can be frequently employed throughout the season as a warm-up to monitor health status of the players, residual fatigue, and adaptation.

5.8 Anaerobic capacity

The anaerobic capacity is defined as the maximum amount of energy that can be produced from the alactic and lactic anaerobic energy systems during a short period of high-intensity exercise (Bouchard *et al.,* 1991; Maughan *et al.,* 1997). High-intensity activity and fatigue are two main factors of contemporary soccer match-play. Understanding the potential limiting factors related to a sporting activity is essential for programme design to delay fatigue and enhance performance (Stone and Conley, 1994).

Mohr and colleagues (2005) have suggested that fatigue or a reduction in performance occurs at various phases within a soccer game. Most notably, fatigue transpires in both the first and second halves of soccer games following short-term intense periods of activity. Secondly, during the initial phase of the second half of a match and thirdly towards the latter stages of the game a form of fatigue is apparent. Temporary fatigue following intense actions within a game does not seem to be directly associated with muscle glycogen concentration, lactate accumulation, acidity or the breakdown of creatine phosphate, and the causes of a reduced ability to perform during a game are unclear (Bangsbo *et al.,* 2006). However, the reduction in performance capabilities within a game has been suggested to be associated with disturbances in muscle ion homeostasis and an impaired excitation of the sacrolemma (Mohr *et al.,* 2005). During high intensity activity an accumulation of lactic acid and corresponding hydrogen ion concentration (H^+) have a negative effect on energy pathways and muscle contractions. An increase in H^+ inhibits glycolytic reactions, particularly phosphofructokinase as well as phosphorylase.

Also, within muscle fibres there is a direct interference of the excitation-contraction coupling, perhaps via inhibition of calcium binding to troponin or by intervention of cross bridge formation (Stone and Conley, 1994). What is more, accumulating H^+ ions and subsequent fatigue are associated with pain, impending exhaustion, as well as discomfort (Parkhouse and McKenzie, 1984). There are major individual differences between players with regards the physical demands within a game that are related to their physical capacity and their tactical role within the team (Bangsbo *et al.,* 2006). Consequently, various absolute exercise intensities will cause different levels of fatigue or performance reductions within soccer players. The degree of fatigue with regards the amount of distance covered at high-intensity running speeds (>18 km/h) during 5 min periods within a soccer game has been reported by Mohr and co-workers (2003), with clear distinctions between elite and moderate soccer players. For further information regarding lactic acid and fatigue, readers are directed to (Hermansen 1981; Hultman *et al.,* 1986; Sahlin 1986; Noakes and St Clair Gibson, 2004).

Blood lactate concentrations of a 4 $mmol \cdot l^{-1}$ threshold has been termed the onset of blood lactate accumulation (OBLA); this standardised value has been suggested to be the point at which there is an imbalance between blood lactate removal and production (Cheng *et al.,* 1992). However, despite findings that lactate threshold is associated with performance measurements, lactate threshold often does not reflect the intensity of competition and may be a questionable benchmark used to prescribe training intensities for sport (Keneflick *et al.,* 2002). Nichols and co-workers (1997) found heart rates in cyclists at lactate threshold were 88% of HR_{max}, and this value was significantly lower than the heart rates stimulated in a time trial (92-94% HR_{max}). Furthermore, the investigators reported that the cyclists were able to perform for extended periods at blood lactate concentrations significantly higher than those at lactate threshold.

The individual's lactate-removal capability plays a crucial role in the in the pattern of blood lactate concentrations during exercise (Oyono-Enquelle *et al.,* 1990). Therefore the ability of a fixed lactate concentration value to predict anaerobic threshold has been questioned, and alternative threshold models have been proposed including the continuous (Hughson *et al.,* 1987) and individualised (Weltman, 1995) methods.

Moreover, blood lactate concentrations taken during soccer matches have ranged between 2.4 and 15 mmol.l^{-1} with the average range between 4 and 6 mmol.l^{-1} (Agnevik 1970; Bangsbo *et al.,* 1994; Ekblom, 1994; Shephard, 1999). Furthermore, lactate responses are influenced by diet, a high-carbohydrate diet shifting the lactate curve to the left (Reilly and Bryant, 1986). Thus, the practical value of a 4 mmol·l threshold test with regards professional soccer is limited. As an indicator of performance, OBLA is at best only a descriptor of a non-soccer specific running task. Also, the information generated with regards steady state training velocities has debatable value for training purposes of an intermittent sport such as soccer.

Anaerobic glycolytic training is one of the most potent methods of facilitating peripheral adaptation and as a result, postponing fatigue. It has been suggested that athletes should experience high lactate levels to enhance the efficiency of the mechanisms of systemic lactate removal. Subsequently, the inhibitory effects of hydrogen ions (H^+) within the muscle cell are reduced, as similar quantities of lactate produced during high-intensity exercise are associated with lower pH values. This superior efficiency of the mechanisms of lactate removal includes a rise in the density of lactate and H^+ transporting proteins, improved blood flow, increase in buffering capacity of H^+ as well as, greater potassium retention (Brooks *et al.,* 1995; Pilegaard *et al.,* 1999; Bassett and Howley, 2000; Carsten *et al.,* 2004). Currently, the choice of suitable tests that facilitate accurate control of adaptive changes in a soccer player's anaerobic capacity from a training stimulus is inadequate, and a solution to this problem has not yet been determined (Bangsbo, 1997; Hoff and Helgeurd, 2004; Sands *et al.,* 2004). Chapter two will attempt to address the problem of a soccer-specific anaerobic capacity test, through a pilot study of the *Liverpool Anaerobic Speed Test,* in order to complete the soccer-specific battery of tests for implementation during Ramadan.

5.9 Anaerobic power

Anaerobic power, corresponds to a player's capability to produce force rapidly, and is defined as the maximal rate of anaerobic energy production generally up to 15 seconds (Baechle, 1994; Ekblom, 1994). Anaerobic power, includes two of three energy systems within its definition, the immediate and nonoxidative but not the oxidative system (Brooks *et al.,* 1995). The major contribution of energy to facilitate a player's maximal power comes from the immediate alactic energy supply that consists of high-energy intramuscular phosphagens (ATP, phosphocreatine -PCr) (Hultman *et al.*, 1983).

5.10 Anaerobic power and soccer

Discrete anaerobic power activities are involved in crucial moments of the game, and often make a notable contribution to the final outcome of a soccer match. Anaerobic power is a key factor in acceleration, quick stop and start movements, as well as rapid changes of direction that take place often during a soccer match (Ekblom, 1994). Also, there are roughly 8-9 jumps per player during a game of professional soccer (Withers *et al.*, 1982; Bangsbo, 1994). Strikers and central defenders jump the most during a game, and may be required to jump once every 5-6 minutes from both a static or dynamic starting position (Reilly and Williams, 2003).

Average values for height of a vertical jump in professional soccer players range from 54-60 cm (Ekblom, 1986; Gauffin *et al.*, 1989; Reilly, 1990; Hoff and Helgerud, 2004). Sprinting in professional European soccer has been classified as running at 30 $km \cdot h^{-1}$. The number of sprints made by a top class professional is 39 ± 2 and equates to a distance of around 0.65 ± 0.06 km. In contrast moderate professional players perform significantly less sprints during a game (n= 26 ± 1) producing a distance of roughly 0.41± 0.03 km (Mohr *et al.*, 2003). There is typically 2-3 second all-out sprints every 90 seconds in a match (Reilly, 1990). Other research has noted 127-183 high-speed runs or sprints are made in an English professional game, and the distances of the sprints will vary from 1 to 5 yards (0.9-4.64 m) to ≥ 40 yards (36.6 m). Further, Dutch professional players of all positions have been reported to make a greater number of total runs and sprints during a game, in comparison to English professionals (Verheijen, 1998). However, the speed was not provided, so it is difficult to compare exactly with the findings of Mohr and co-workers (2003).

The research is lacking in notation analysis of soccer within the Gulf area, so no direct comparison can be made with Qatari players. Hazzaa and colleagues (2001) are the only investigators within the region to have collected data on anaerobic power in Saudi international players. However, they used the non-soccer specific Wingate test with an average power of 10.08 ± 0.55 $W.kg^{-1}$ (5 s) which is a lower value than has been reported in other soccer professionals (Brewer and Davis, 1991).

5.11 Vertical power tests

The jumping movement can be broken down to separate components each of which has the potential to limit or improve performance. Muscle strength, power (rate of force development -RFD) and coordination (Oddsson and Westling, 1991) are all key elements. Therefore, in order to evaluate the discrete components of jumping, several jump tests are necessary. The multi-jump approach assists the practitioner in programme design of more individualized specific programs for soccer players within a squad environment, facilitating more productive training interventions within the players' conditioning, and evaluation of effectiveness (Ekblom, 1994). As one jump takes a matter of seconds and only a short rest period ($\leq$ 1 min) is necessary between jumps, the different kinds of jump (Table IX) can easily be accommodated with soccer squads.

Table IX: Jump test options for soccer players.

Jump Test Options
1. Bounce Jump timed 2. Counter-Movement Jump with Arms - CMJ 3. Counter-Movement Jump No Arms- CMJNA 4. Sergeant Jump 5. Soccer specific Suspended Ball Jump 6. Single leg Hop 10 m 7. Standing Broad Jump-SBJ 8. Standing Triple Jump adds bit more co-ordination 9. Rocket Jump 10. Vertical drop Jump

(Ekblom, 1994; Hodson, 2000)

Soccer-specific jumping usually involves a run with a couple of steps and a one-foot take-off, with a 3-5-stride approach producing the greatest height. Despite the ecological validity of such assessments, the test-retest reliability decreases with an increasing number of steps (Young *et al.,* 1997). A number of maximal jumps may be employed from the table in the test battery, Rocket jump, CMJNA, CMJ, SBJ, Single-leg 10-m hop were selected for the purpose of this investigation.

The "Rocket Jump" is performed from an isometric start in a flexed position within the comfortable range of motion for the player. The jump provides an estimate dynamic concentric work produced mainly by the hip, knee, and ankle extensors (Ekblom, 1994). The counter-movement jump no arms (CMJNA), is started from an upright position with hands on the hips throughout the duration of the test; this procedure isolates the legs by removing the upper body contribution of arm swing.

The CMJNA measures eccentric-concentric power of the lower limbs; this stretch-shortening muscle action is involved in all movement patterns within sport and exercise walks, running, sprints, jumps changes of direction (Siff, 2003), and may account for roughly 40% of total force production (Ekblom, 1994). Counter-movement jump (CMJ) with arms is a progression of the CMJNA, and includes the coordination and power of the upper limbs to the action. The inclusion of both styles of counter-movement jump has been recommended (Ekblom, 1994).

5.12 Horizontal Power

Horizontal power has been highlighted as a key factor in fast running speed, with ankle extension at push off, knee drive, as well as arm movements all contributing to successful sprinting (Yessis, 2001). Therefore it is logical to evaluate horizontal power from an isometric start, looking at horizontal starting strength and acceleration strength (Siff, 2003). Horizontal static power may be evaluated indirectly via a standing broad jump (although power performance is not measured). Limb length of the individual will have an influence on results, and so within subject comparisons are applicable with SBJ evaluation rather than between subjects. The average standing broad jump of soccer players is roughly 2.2 m (Reilly, 1990).

The support phase of sprinting is another main factor relevant to running fast. It is known as the *amortization* phase, a common term in sprinting and plyometrics activity. It lasts for the duration of ground contact beginning with dorsiflexion and ending with a powerful ankle extension, the duration of amortization lasting roughly 0.1 s in world-class sprinters (Yessis, 2001). The single-leg hop test facilitates the comparison of individual lower limbs and helps to identify imbalances. The single hop test over 6 m has also been employed as an indicator of recovery of anterior cruciate ligament injuries with soccer players (Roi *et al.,* 2003). Reliability coefficients for both a single-hop test for distance and a set distance hop for time have been found to have a high correlation (0.92 to 0.97) over a 4-week interval (Ross *et al.*, 2002). This observation indicates that both the SBJ and 10-m hop test are reliable methods of assessments.

5.13 Speed

Speed is a natural component of soccer fitness to evaluate, and contributes to roughly 11% of total distance covered; the average sprint distance for a soccer player during a match is between 10-30 m with the mean duration of 2 s and top end less than 6 s (Reilly and Thomas, 1976; Bangsbo *et al.,* 1991). Usually 10-m, 20-m, or 30-m assessments are made with soccer players (Kollath and Quade, 1993; Studwick *et al.,* 2002). To evaluate acceleration of a soccer player, a distance of 5-15 m is recommended (Ekblom, 1994). The 10-m sprint test provides an indication of peak power that the phosphate system can deliver and the test duration is under 2 s (Verheijen, 1998). The 30-m sprint test is applicable for evaluating a player's rate of acceleration to peak velocity; peak velocity in top class soccer matches has been noted at 32 $km \cdot h^{-1}$ (Bangsbo *et al.,* 2006). The 30-m sprint test duration is around 4-5 seconds (depending on ability of player) and measures both the power and capacity of the phosphate energy system (Verheijen, 1998). Further, Hoffman and Kaminsky (2000) noted that the 27-m sprint was the most sensitive test for highlighting basketball players in a fatigued state. They used an increase in sprint time of 0.15 seconds of the players' best sprint time as a red flag amongst the support staff to warrant further investigation of the player's physical condition, demonstrating the practical use of speed tests within season. However, the reliability of a 0.15 s increase in 27-m sprint time does warrant further investigation in order to provide more precise guidelines. Hoffman and Kaminsky (2000) selected this value arbitrarily rather than from a more scientific approach using limits of agreement or coefficient of variation calculations.

Flying starts provide the sprint assessments with more ecological validity as very few sprints are performed from a static start in soccer (Svensson and Drust, 2005). This measurement is a by-product of placing the photoelectric cells at 10 m and 30 m, producing a 10-m flying start and measuring the intermediate 20 m. This additional measurement adds no further time to administration of the test battery procedures. Studies evaluating flying start sprints with soccer players are lacking.

Approximately 7% of the game is spent moving backwards, that is more than in actual contact with the ball (2%); backward running is involved during tactical repositioning especially with central defensive positions, and creating space to receive a pass (Reilly and Williams, 2003). Top class players spend more time running backwards in contrast to moderate players (Mohr *et al.,* 2003). Moving backwards involves running on the balls of the feet as the heels are never in contact with the ground. It requires quick feet, coordination and power and although practiced in conditioning drills (Brown et al., 2000), it is seldom tested. Consequently, there is a lack research on back-pedalling. The backward-sprint test can easily be accommodated within a test session as it takes minimal time for a squad of players.

5.14 Agility

Speed and agility are two fitness components that correlate positively with soccer yet they should be evaluated separately; evidence is that the transference of speed training to agility and vice versa is minimal. Also, the more complex the agility task, the less pure speed training transfers across (Young *et al.,* 1995; Little and Williams, 2003). Agility is often described as the ability to stop, start, and change direction quickly. Direct speed accounts for only 10% of average agility time. The other 90% of unaccounted variance consists of many influential factors of movement that take place both simultaneously and in sequence; these include balance, co-ordination, flexibility, reaction time, rate of deceleration and subsequent acceleration (eccentric, isometric, concentric strength), power, speed, technical proficiency in the ability to cut and change direction (with regards position of foot plant around the object) (Buttifant, 1998; Roper, 1998; Young *et al.,* 2001).

There is no single gold standard agility test to use with soccer players (Svenson and Drust, 2005). Consequently, many tests have been employed to evaluate agility within sports (505, T-test, Illinois agility, Balsom soccer agility test). Further, some agility tests have stronger correlations with aspects of speed in comparison to others. The Illinois agility test has a strong correlation with both acceleration and velocity. Conversely, the 505 agility test demonstrates no significant correlation with velocity but an association with acceleration (Getchell, 1979; Draper and Lancaster, 1985; Balsom, 1994; Paoule *et al.,* 2000)

Given the lack of guidance for a soccer-specific agility test, the selection for this thesis will be based around practicality and specificity. The 20-m Zig Zag test will be employed (Buttifant and Graham, 1999) to evaluate agility of soccer players, since the layout of agility cones can easily be accommodated within the set up for straight line speed.
Such organisation will facilitate administrating the testing battery smoothly and allow other tests to be included within a short time frame. The specificity of the test includes left and right cutting movements. It has also been found to be a reliable measurement and sensitive enough to differentiate between the speed and agility components of sport. However, the drawback of the test in comparison to other agility assessments is that there is no backward or pure lateral movement.

5.15 Repeated sprint ability (RSA)

Soccer players must be cable of rapid recovery between sprints as determined by the random demands of the game and several authors have proposed repeated sprint ability protocols with soccer in mind (Balsom *et al.,* 1992a; Bangsbo, 1994; Verheijen, 1998). However, the duration and number of repetitions vary and consequently the energy demands of the respective tests are different. One of the biggest problems with repeated sprint ability tests is that there is no clear definition of the test criteria. As a result, there are no current laboratory gold standard repeated sprint ability tests to compare against a respective field measure. Therefore, no repeated sprint ability test can at this stage be included within the soccer specific battery of tests to be employed in the investigation protocol for this thesis.

5.16 Player profile

The performance tests that are selected fit into part of a systematic structure within the professional soccer club and form part of a player profile (Figure 2). The purpose of the player profile is to give a breakdown of the players' separate soccer-fitness components, and provide feedback to both coaches as well as players on fitness condition.

Al-AHLI

Football Physical Player Profile

Squad:		Physiological Assessment Date:	
Name:		Training week:	
Squad Number:		Religion:	
Position:		Football Physical Team Performance Rank:	

	Individual Results	Positional (Defence) Range of Results	Squad Range of Results	Test Rank	Elite Profesionals Top/ Range of Results
Anthropometrics:					
Weight kg:					77kg +/ - 8.9
Height cm:					
Sum of skinfolds:					
Body fat %					9-12%
DOB: Age:					
Aerobic Tests					
Bleep Test-VO2 Max					
Level					(14.8)-16:0-(17.4)
Shuttle					
Vo2 Max					67.6+/- 4.0 mL.kg-1.min-1
Max HR		220-Age(30) =			
Training Heart Rates	**HR Zones**	**Target**	**Range**		
5. Very High Intensity	90-95/100%	(Target 93%)			
4. Moderate - High Intensity	80-90%	(Target 85%)			
3. Low to Moderate Intenisty	70-80%	(Target 75%)			
2. Recovery intensity	60-70%	(Target 65%)			
1. Morning Resting Heart Rate	Testing Day 1=	Testing Day 2 =	Testing Day 3 =	Average Resting HR =	
Yo-Yo Intermittent Recovery (9 mins)		Squad Average-9mins			
%HR max					81%
Yo-Yo Intermittent Recovery Test (m)					3025 +/ 432m
Anaerobic Tests					
WASPT-Speed Endurance					
1st Rep Meters/bpm/%maxHR	m bpm %MHR	m bpm %MHR	m bpm %MHR		310 m bpm %MHR
2nd Rep Meters/bpm/%maxHR	m bpm %MHR	m bpm %MHR	m bpm %MHR		289 m bpm %MHR
3rd Rep Meters/bpm/%maxHR	m bpm %MHR	m bpm %MHR	m bpm %MHR		273 m bpm %MHR
Best Score	m	( )-( ) m	( )-( ) m		310 m
Total Distance	m	( )-( ) m	( )-( ) m		872 m
Mean Distance	m	( )-( ) m	( )-( ) m		291 m
Fatigue Index	m	( )-( ) m	( )- -( ) m		37 m
Recovery HR (BPM/%) 1-Min Post Rep 3	bpm/ %HRmax	/ %HRmax	bpm/ %HRmax		
Vertical Power					
Rocket Jump	cm	( )- -( ) cm	( )- -( ) cm		54 cm
CMJ (No Arms)	cm	( )- -( ) cm	( )- -( ) cm		55 cm
CMJ	cm	( )- -( ) cm	( )- -( ) cm		63 cm +/- 5.7
Horizontal Power					
Static-SBJ	cm	( )- -( ) m	( )- -( ) m		295 cm
Dynamic- 10m Single leg Hop					
Left	s	( )- -( ) s	( )- -( ) s		1.53 s
Right	s	( )- -( ) s	( )- -( ) s		1.79 s
Speed Test					
10 m	s	( )- -( ) s	( )- -( ) s		1.41 s
30 m	s	( )- -( ) s	( )- -( ) s		3.68 s
Flying 20m	s	( )- -( ) s	( )- -( ) s		2.27 s
Backwards 10m	s	( )- -( ) s	( )- -( ) s		1.91 s
Agility 20m Zig Zag					
Right	s	( )- -( ) s	( )- -( ) s		3.47 s
Left	s	( )- -( ) s	( )- -( ) s		3.54 s

Feedback and Recommendations:

1. Anthropometrics
2. Aerobic Power
3. Sub Maximal Aerobic
4. Hybrid Aerobic/Anaerobic
5. Ananerobic Capacity
6. Votical power - Concentric
7. Vertical Power - SSC
8. Verical Height Jump
9. Horizontal Power Static
10. Horizontal Power Dynamic
11. Short Spint 10m
12. Long Sprint 30m
13. Flying Sprint 20-m
14. Backward Speed 10-m
15. Agility Left Empahsis
16. Agility Right Empasis

Figure 3. Player profile sheet used to provide feedback to coaches and players.

6.0 Summary of literature review

Professional soccer is a sport that involves intermittent exercise engaging all energy systems at some point during match-play. The research surrounding Qatari professional players is lacking, and so a generic overview was provided to give an indication of the physiological requirements of soccer players during match-play and types of training. Environmental stress in Qatar introduces greater physiological challenges of temperature regulation and body fluid loss to the Qatari professional soccer player, in contrast to players playing in more ambient climates. Consequently, dehydration is a major concern for Qatari soccer players during both soccer practice and matches. In accordance with dehydration during exercise, core temperature is elevated by 0.15°C to 0.20 °C for every 1% of body weight lost associated with sweating (Sawka et al., 1985; Montain and Coyle, 1992). This increase in body temperature transpires from both impaired skin blood flow and altered sweating responses (Buskirk *et al.,* 1958; Casa *et al.,* 2000). These thermoregulatory adjustments can negate the physiological advantages that have been produced from enhanced fitness levels (Cadarette *et al.,* 1984) as well as heat acclimatisation (Buskirk *et al.,* 1958; Casa *et al.,* 2000). Furthermore, if a player commences training or matchtes in a hyophydrated state, heat tolerance is reduced (Sawka et al., 1992). The degree of fluid loss for Qatari players during matches and training is unknown, and the effects of chronic dehydration on training and match-play performance is unclear.

The effects of the lifestyle changes necessitated by adherence to Ramadan have received little attention with respect to research on professional athletes despite, major sporting events coinciding frequently with this religious intervention. Circadian adjustments dehydration, and negative energy balance are all key factors that are capable of providing additional stress on the soccer player and have the potential to limit performance capability. It has been suggested that during Ramadan circadian variation is a hybrid of ageing, jet-lag, and shift-work models (Reilly and Waterhouse, 2007).

To assist with the investigation's research questions, a soccer-specific battery of tests is necessary of which there is no universally accepted gold standard battery. The focus of this aspect of the review was based around the discrete soccer fitness components that have been highlighted within the demands of match-play and training for the game; in order to produce an applicable and practical battery of soccer tests.

In brief, soccer is a demanding sport requiring many aspects of physical capacity during match-play. The Qatari professional soccer players also have to contend with additional physiological stress provided by the hot and humid environment within the Arabian Gulf. Therefore, the addition of the religious intervention of Ramadan and the associated lifestyle changes with this scenario provide a set of circumstances that are some of the most challenging within the sport of soccer. A schematic overview of the work to be undertaken can be found in Figure 3.

The effects of intermittent fasting during Ramadan on performance related to football (soccer).

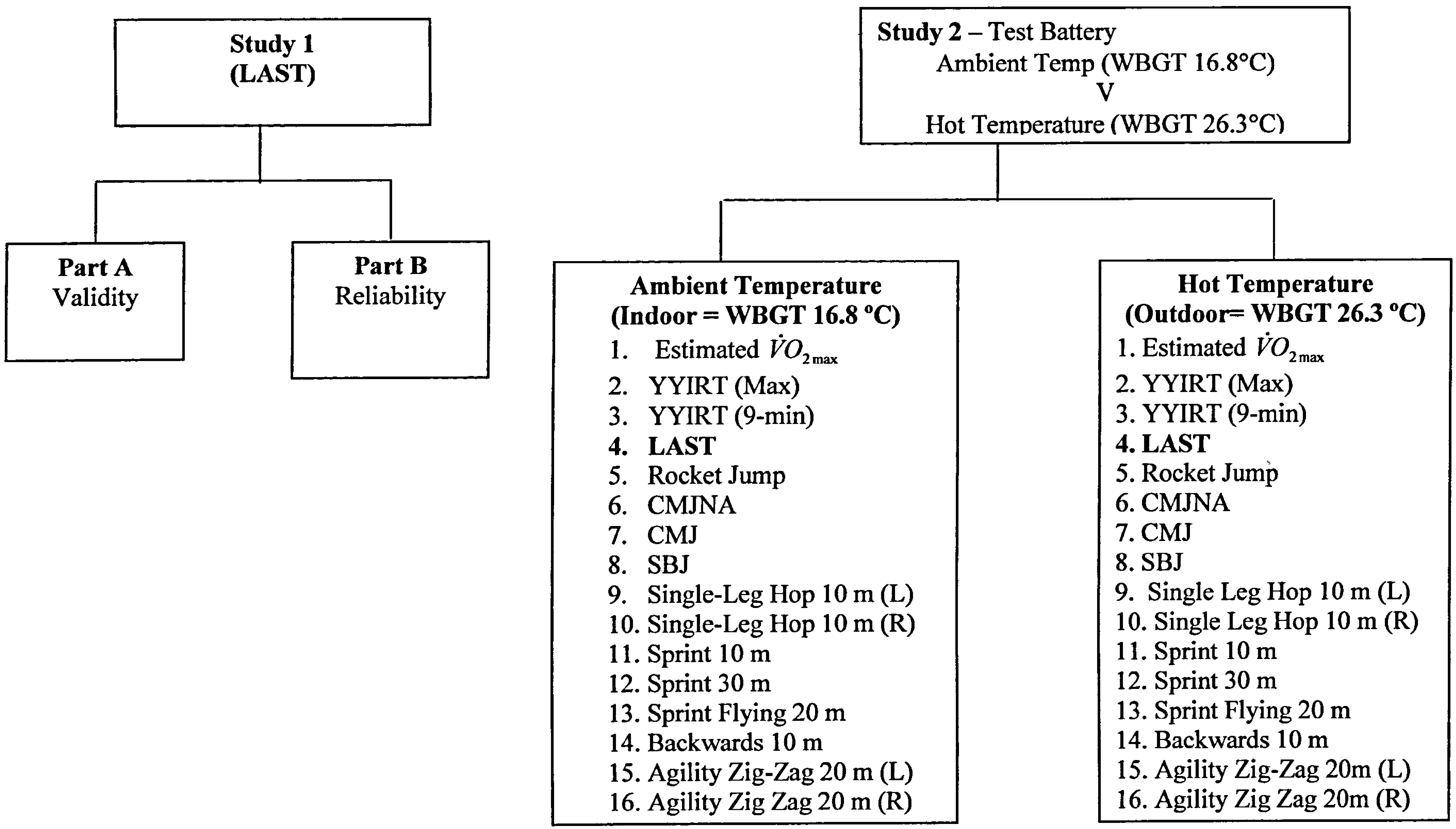


Figure 4a. Schematic overview of studies to be conducted as parts of the thesis.

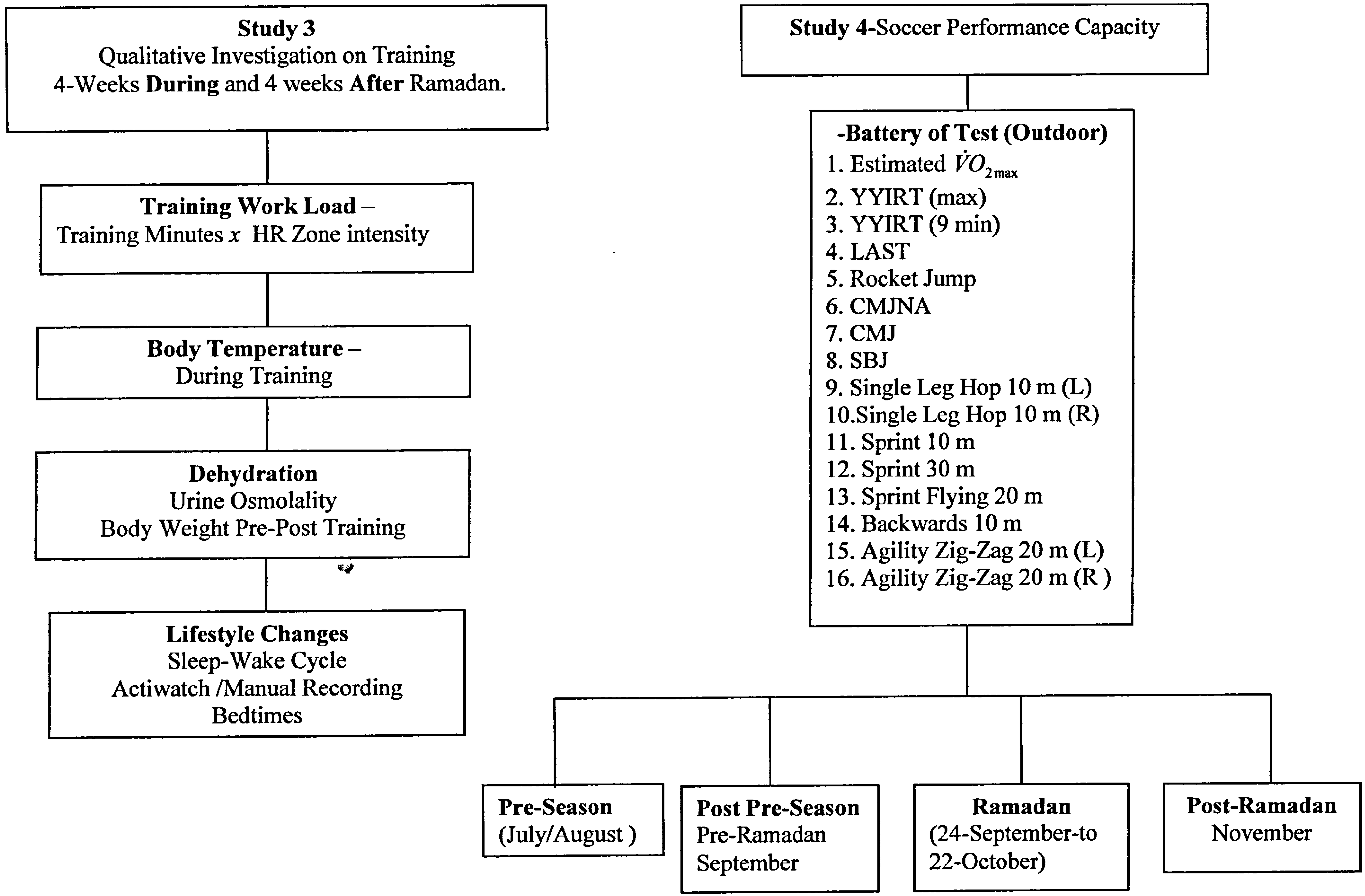


Figure 4b. Schematic overview of studies to be conducted as parts of the thesis.

Chapter 3

Study 1: Pilot Study of a Soccer-Specific Field Test of Anaerobic Capacity Liverpool Anaerobic Speed Test (LAST)

7.0 Part A - Reliability

7.1 Introduction

Reliability is the degree to which a test or measurement can be repeated (Thomas and Nelson, 1996). In this preliminary study, the reliability of the Liverpool Anaerobic Speed Test (LAST) was evaluated first since a test cannot be accepted as a valid measurement if it is not reliable (Atkinson and Nevill, 1998). The anaerobic capacity is defined as the maximum amount of energy that can be produced during a short period of high-intensity exercise (Bouchard *et al.,* 1991). Several investigators (Table XII) have employed different protocols involving various durations of high-intensity activity in order to evaluate anaerobic capacity. However, Balsom (1988) has observed that the duration of 1 min in an anaerobic capacity jump test produced the best correlation with performance in a simulated soccer test.

Soccer has long been established as a high-intensity game involving semi-random unpredictable patterns of play that vary from game to game. Contemporary work-rate profiles of elite soccer players have indicated a marked improvement in the tempo of games. In contrast to the old First Division, modern match-play in the English Premier League has been observed to include a greater number of passes, involvements with a ball, dribbling, crossing, and total distance covered (Studwick and Reilly, 2001). Players typically have to run at cruise speed (sub-maximal striding) or sprint every 30 seconds, and around every 90 seconds perform an all-out sprint. High-intensity running and sprinting account for about 15% of the total distance covered (Reilly and Thomas, 1976; Mohr *et al.,* 2003) and these anaerobic activities are widely accepted within the soccer industry as essential for successful individual and team performance (Reilly and Williams, 2003).

Elite European soccer professionals have been observed to carry out between 150-250 short intense actions within a game (Bangsbo *et al.,* 2006). Furthermore, the amount of high-intensity running was found to differentiate standards of play as well as the role of players. Yet, it was also reported that there are detrimental consequences of performing such high-intensity bouts within a match. Peak high-intensity distance covered in a 5-min bout during a game ranged from 219 ± 8 m to 172 ± 9 m for top class and moderate players, respectively. In the 5-min period of play that followed, this volume was reduced to 106 ± 6 m and 94 ± 8 m respectively, and these figures were significantly below game average values. Further, the amount of high-intensity running during a game regardless of playing standard or position was significantly lower during the final 15 min in comparison to any other part of the game by as much as 35-45%. In contrast to players who start the game, substitutes were also found to cover 25% more ground at high-intensity running speeds during this latter part of the game (Mohr *et al.,* 2003).

Thus, it is clear that high-intensity activity and fatigue are two key factors of contemporary soccer match-play. A high anaerobic capacity is a central factor to performing repeated fast bursts of activity during a game (Reilly and Williams, 2003). So, it seems logical to address and evaluate this component of soccer fitness.

The traditional gold standard anaerobic capacity test is the Wingate Cycle Test that is typically conducted within a laboratory environment. Several soccer studies have employed this protocol to evaluate players. Al-Hazzaa and co-workers (2001) and Mangine and colleagues (1990) found that for Saudi and USA national team players anaerobic capacities were 8.02 ± 0.53 $W.kg^{-1}$ and 8.1 $W.kg^{-1}$, respectively. In contrast to the aforementioned findings, Brewer and Davis (1991) noted Swedish national players had superior anaerobic capacities producing 13.5 $W.kg^{-1}$. Moreover, there are other anaerobic capacity protocols that have been carried out with professional soccer players that involve a repetitive jump design. Reilly (1990) considered the use of a 60-s repeated jump approach, reporting a power output of 23 $W.kg^{-1}$ in soccer players.

The values reported within these studies are at best only a descriptor of anaerobic performance, and provide limited practical value regarding training programme interventions for professional soccer players. Also, one cannot validly compare power output on a cycle to a jump test, and so objective comparisons of performances between players are impeded. Furthermore, it is not clear how well do these two non-soccer specific activities transfer to high-intensity running and recovery in soccer. This lack of clarity and consistency hinders objective comparisons, creates ambiguity, as well as questions the practicality of the data produced regarding professional soccer players. When using elite athletes for assessment, the validity of employing an anaerobic test is dubious if the only result from data produced is a crude value of maximal anaerobic capacity or power (Shephard, 1999).

It is best to assess anaerobic performance in terms of a soccer-specific field test with particular focus on the capability of performance over successive sprints (MacKay and Shephard, 1988; Balsom, 1990). The current menu of suitable tests that facilitate accurate control of adaptive changes in a soccer player's anaerobic capacity from a training stimulus is inadequate. A solution to this problem has not yet been determined (Bangsbo, 1997; Hoff and Helgeurd, 2004; Sands *et al.,* 2004).

The purpose of this study is to pilot a soccer-specific anaerobic capacity field test, the Liverpool Anaerobic Speed Test or LAST. Its application requires that is satisfies criteria for reliability, validity, and practicality.

7.2 Liverpool Anaerobic Speed Test (LAST) design

The LAST is a series of 3 consecutive 60-s time trials (total of 3-min work) separated by 60-s passive recovery periods (Figure 5). Each time trial is measured to the nearest metre, and total distance covered (metres) from all 3-time trials provide an indirect user-friendly measurement of anaerobic capacity performance. The LAST *work:rest* ratio of 1:1 is based on the notion of anaerobic capacity development using speed-endurance maintenance, and the ability to sustain high-intensity exercise (Bangsbo, 1994). This work intensity follows several soccer specific conditioning drills that have been designed to develop the anaerobic capacity (Wilson, 2001; Bangsbo, 2003; Reilly, 2003).

The test design has been modified from the 300-m shuttle run used by many collegiate and professional teams in the USA (Baechle, 1994); it involves soccer components (acceleration, speed, deceleration, speed endurance, as well as recovery) all within a competitive environment. Furthermore, the LAST includes specific soccer turns at the end of each 25-m run with a basic inside push pass of a stationary ball 3 m to a team-mate or coach. The ball task provides motivation for players, as well as ensures greater control of the test by making sure the player goes to each line and no *cheating* transpires (turning before they have reached the line).

The data collected in the LAST are expressed in metres from each 60-s time trial in contrast to the original 300-m shuttle design that records time taken. This form of data compilation makes it possible for large numbers of players of various fitness abilities within a squad to be tested simultaneously, and facilitates tighter control of the standardised interval rest periods. Moreover, many players especially of a lower level are likely to take longer than 1 min to complete a 300-m shuttle run, especially with several repetitions. Therefore, the test then becomes more aerobic and detracts from the objective of anaerobic assessment.

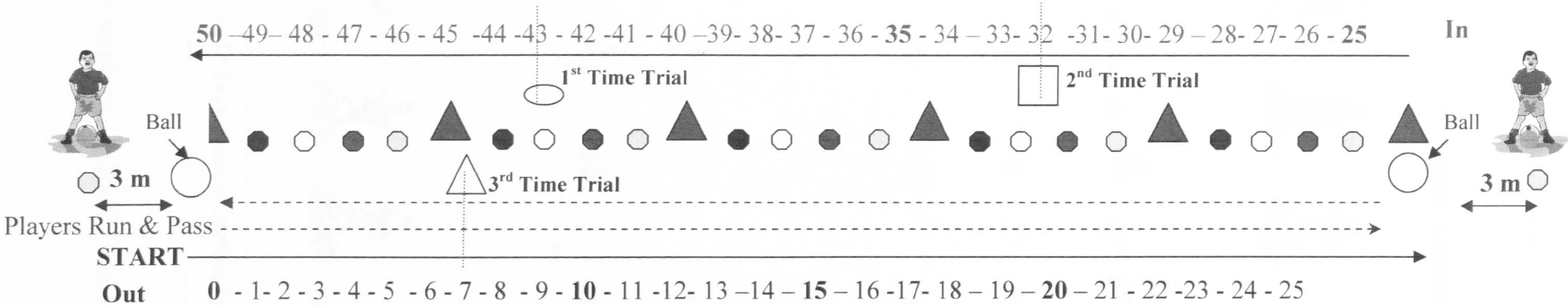
The set-up (Figure 6) and format is time efficient with 1 group of 6-7 players completely tested within 5 min. Thus, an entire squad split into 3 groups can be tested in around 20 min. Therefore, other tests or training tasks can easily be incorporated within the same session. It is acknowledged that during a game it is highly unlikely that a player will ever perform three consecutive high-intensity running bouts back and forth over 25 m continuously for a 1-min period, then rest for 1 min. However in order to investigate the fitness component of anaerobic capacity it is necessary, to sacrifice a little game specificity for objectivity, following a similar rationale for $\dot{V}O_{2\max}$ assessments of soccer players.

Liverpool Anaerobic Speed Test-Example

Squad: .... **Date:** ....

Name: .... **Date of Birth:** ....

Playing Position: .... **Environment:** ....



Total Score m	Key	50 m	100 m	150 m	200 m	250 m	300 m	350 m	+
60 s Time Trial 1 = 250 + 43 = 293 m	○	☑	☑	☑	☑	☑	☐	☐	43
60 s Passive Rest									
60 s Time Trial 2 = 250 + 32 = 282 m	☐	☑	☑	☑	☑	☑	☐	☐	32
60 s Passive Rest									
60 s Time Trial 3 = 250 + 7 = 257 m	△	☑	☑	☑	☑	☑	☐	☐	7

1. **Best score** = 293 **m**
2. **Total distance** = **Time Trial 1:** 293 **m** + **Time Trial 2:** 282 **m** + **Time Trial 3:** 257 **m** = 832 **m**
3. **Mean distance** (total distance /3) = 277 **m**
   Estimated max heart rate = 198 **beats.min^{-1}: 90-95% heart rate max** = 178 **beats.min^{-1}** - 188 **beats.min^{-1}**
4. **Heart Rate** (beats.min^{-1}) **= R1:** 184 **beats.min^{-1}**, R2: 185 **beats.min^{-1}**, **R3:** 184 **beats.min^{-1}**

Figure 5. Data collection sheet for Liverpool Anaerobic Speed Test (LAST)

7.3 Liverpool Anaerobic Speed Test (LAST) set-up

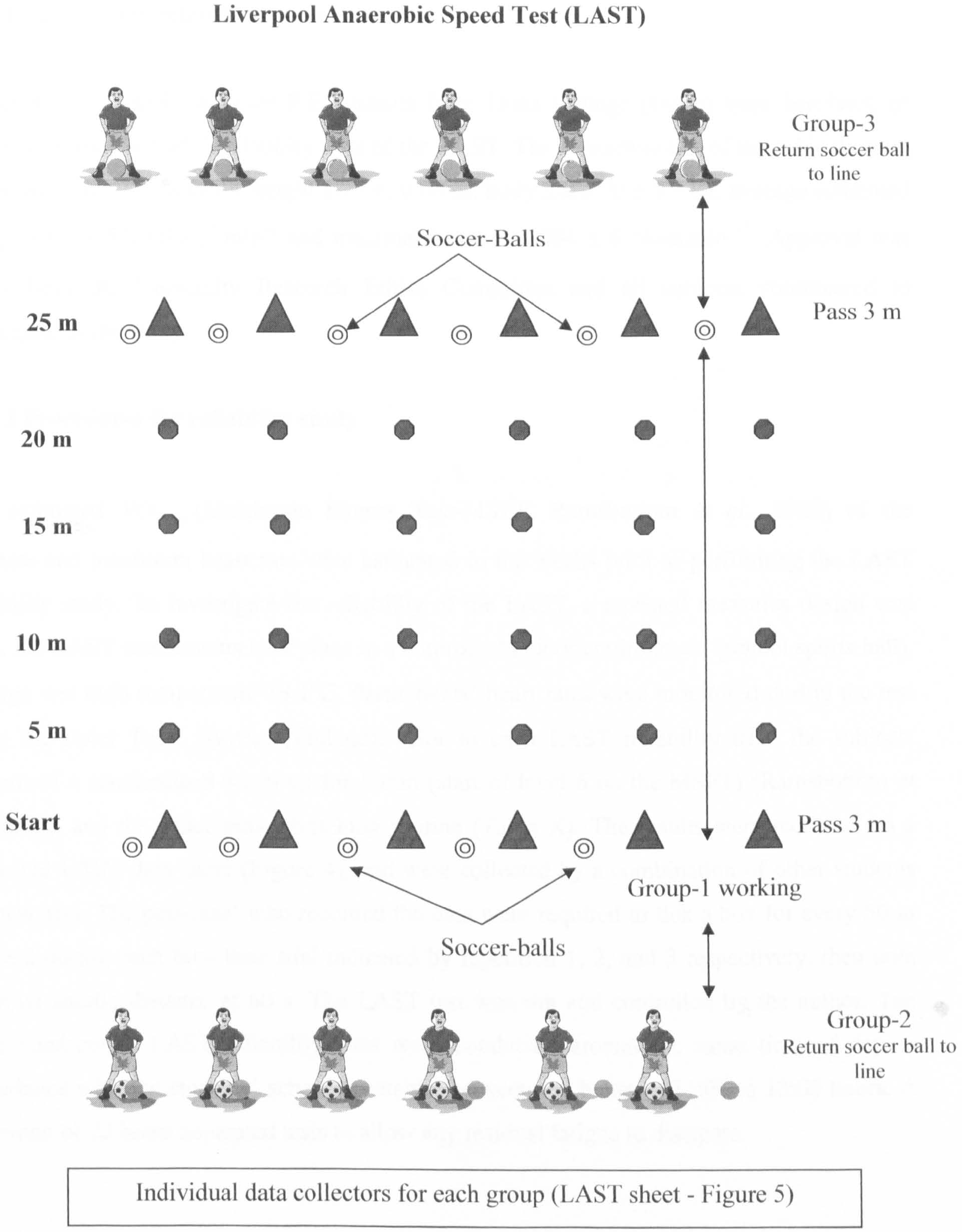


Figure 6. The set-up of the Liverpool Anaerobic Speed Test.

7. 4 Methods

7. 4. 1 Subjects for reliability study

In this study 20 male A-Level P.E students from Doha College (Qatar) were involved, of whom 13 completed all 3 reliability tests of the LAST. The characteristics of the subjects were as follows:- age 17-18 years, height 1.77 ±. 0.04 m, body mass 70 ± 9.2 kg, average estimated $\dot{V}O_{2max}$ 49.6 ± 5.8 ml.kg^{-1}.min^{-1} and maximal heart rate 204 ± 6 beats.min $^{-1}$. Approval was given from the University Research Ethics Committee and all subjects volunteered to participate in the study.

7. 4. 2 Procedures for reliability study

The estimated $\dot{V}O_{2max}$ (Multistage Fitness Test-MSFT, Ramsbottom *et al.,* 1988) of the students and maximum heart rate were estimated in the weeks prior to performing the LAST reliability study. To investigate the reliability of the LAST, a repeated measures design was used. All LAST assessments took place in a controlled indoor environment (school sports hall), average wet bulb temperature 18.1°C. Participants' heart rates were monitored during the test using the Polar Team System (Finland). Prior to each LAST reliability trial, the subjects performed a standardised warm-up for 5 min (start of level 6 on the MSFT) (Ramsbottom *et al.,* 1988), and the exact same stretching routine (Table X). The results were recorded on a dedicated LAST data sheet (Figure 4), and were collected by a combination of other students and teachers. The personnel who recorded the data were required to tick a box for every 50 m covered during each 60-s time trial indicated by repetition 1, 2, and 3 respectively, then note the final shuttle distance at 60 s. The LAST test was run and controlled by the author. The three consecutive LAST reliability tests were conducted around the same time of day in accordance with the students' school timetable, between the hours of 11:00 to 13:00 hours. A minimum of 72 hours separated tests to allow any residual fatigue to dissipate.

Table X: Stretching protocol for test days.

Mobilisation	Static	/ Dynamic Stretching
3-rotations clock/anti-clockwise	10-s hold	/ 3-repetions each leg
Ankles	Gastrocnemius	– Heel walks
Knees	Quadriceps	– Standing on a single-leg bent leg hip-extension/flexion
Hips		
Torso		
	Groins	– Standing on a single-leg rotation/abduction-adduction
	Hamstrings	– Straight-leg forward rise
	2-min additional personalised stretching	

7.5 Reliability statistical analysis:

It has been recommended that several statistical calculations should be used in reliability studies (Atkinson and Nevill, 1998). Firstly, in the examination of heteroscedasticity, the correlation between absolute differences and individual means was positive ($r = 0.24$) but not significant ($p = 0.938$). Also, there were outliers within the data as indicated by long whiskers in the box plot examination, and the distribution had a slight positive skewness as well as kurtosis. Therefore, statistical analysis of the raw data was not applicable and the results were logarithmically (base e) transformed (Atkinson and Nevill, 1998). All calculations were made using the Statistical Package for the Social Sciences (SPSS) (version 14.0). The significance level was set at $P \leq 0.05$.

Descriptive statistics were used to display the mean, standard deviation, and a range of values taken during the LAST reliability tests 1, 2, and 3. Reliability can be assessed by a number of means (Atkinson and Nevill, 1998). A repeated measure ANOVA was employed to explain the differences between the three consecutive LAST assessments. To reduce the possibility of type I errors, Bonferroni correction was used. Coefficient of variation (CV = SD of column of differences/grand mean x 100 was used to explain the variability between LAST tests 2 and 3; the level of acceptance of reliability was arbitrarily set at <10%. Intra-class correlation was used to assess reliability, as it is sensitive to changes in both the order and the magnitude of differences in the mean values between repeated measures (Vincent, 2005). Limits of agreement (LOA) are a measure of total error (systematic bias and random error- biological / mechanical variation) and indicator of absolute reliability. As heteroscedasticity was present, the LOA values are presented as a ratio of LOA. The 95% ratio limits of agreement were calculated from the CV x 1.96 (Atkinson and Nevill, 1998).

7.6 Results of reliability study

The descriptive statistics of the indirect measures of anaerobic capacity (total distance covered from three 60-s time trials during the LAST) recorded during the reliability investigation can be found in Table XI. The repeated measures ANOVA disclosed a significant difference ($F_{1.23, 14.77}$ = 21.10, P< 0.05) between the 3 separate Liverpool Anaerobic Speed Tests. Post-hoc analysis revealed that there was a significant difference between LAST-1 and LAST-2, LAST-3, respectively. Yet, there was no significant difference between LAST-2 and LAST-3, (P=0.73) with a mean total distance difference of 7 m.

The standard deviation of the differences between LAST test-2 and LAST test-3 was 9 m and the grand mean = 733 m. Consequently, the coefficient of variation between LAST test 2 and test 3 = 1.3%. The intra-class correlation between all three discrete LAST assessments was low (R_1 0.51) (Figure.6). However, the intra-class correlation between LAST test-2 and LAST test-3 was high (R_1 0.92). The 95% ratio of the LOA was 2.5% and based on the mean total distance of LAST test-3 (736 m) the total measurement error = ±18 m (see Figure 7).

Table XI: Descriptive statistics for the raw data of the LAST reliability study.

	N	Mean (m)	SD	Range	SE	95%CI
LAST 1	13	703	23	82	6.5	±13
LAST 2	13	730	20	68	5.7	±11
LAST 3	13	736	21	75	5.7	±11

- 95%CI = 95% Confidence interval.

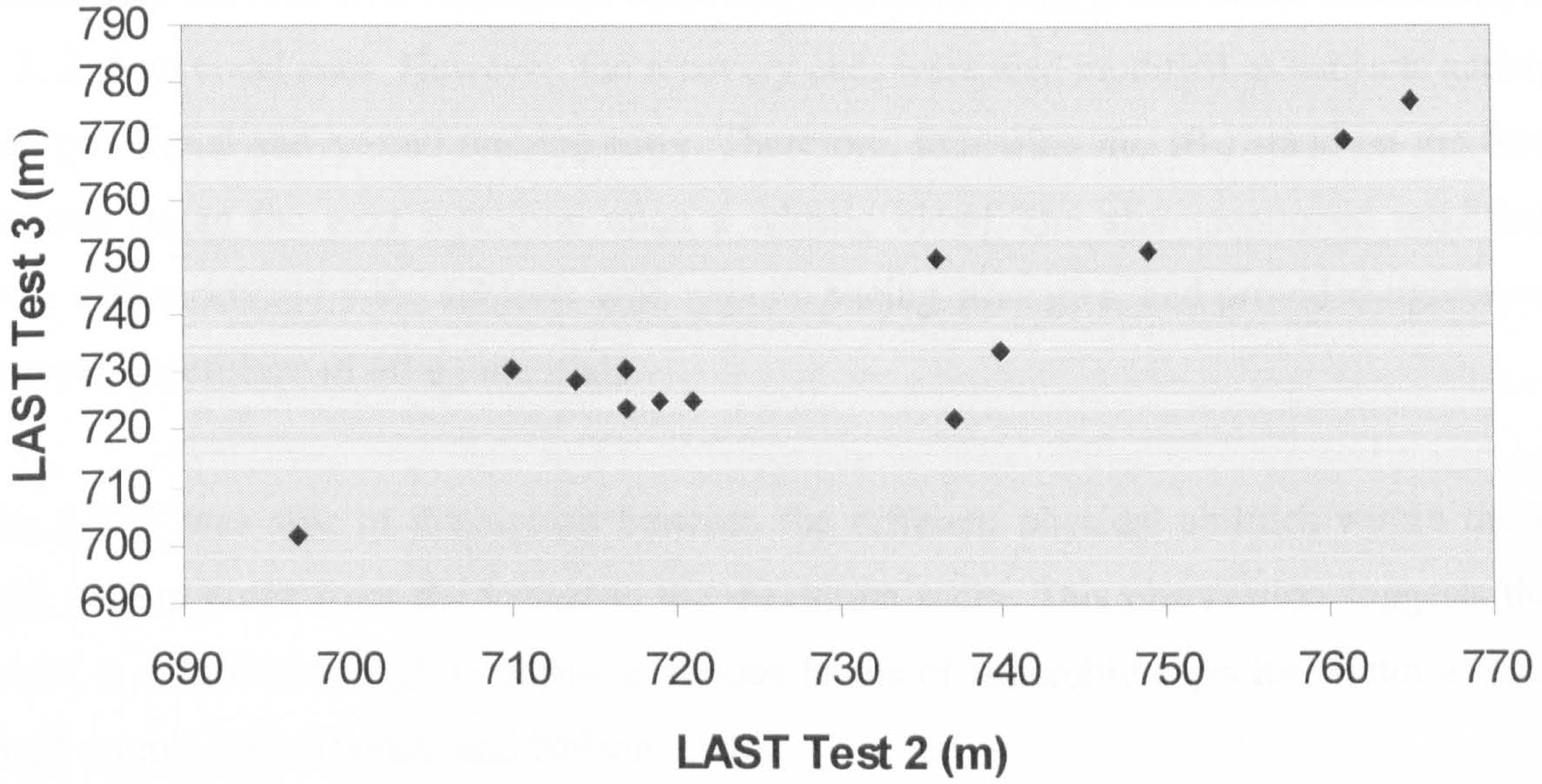


Figure 7. Correlation between LAST Trials 2 & 3.

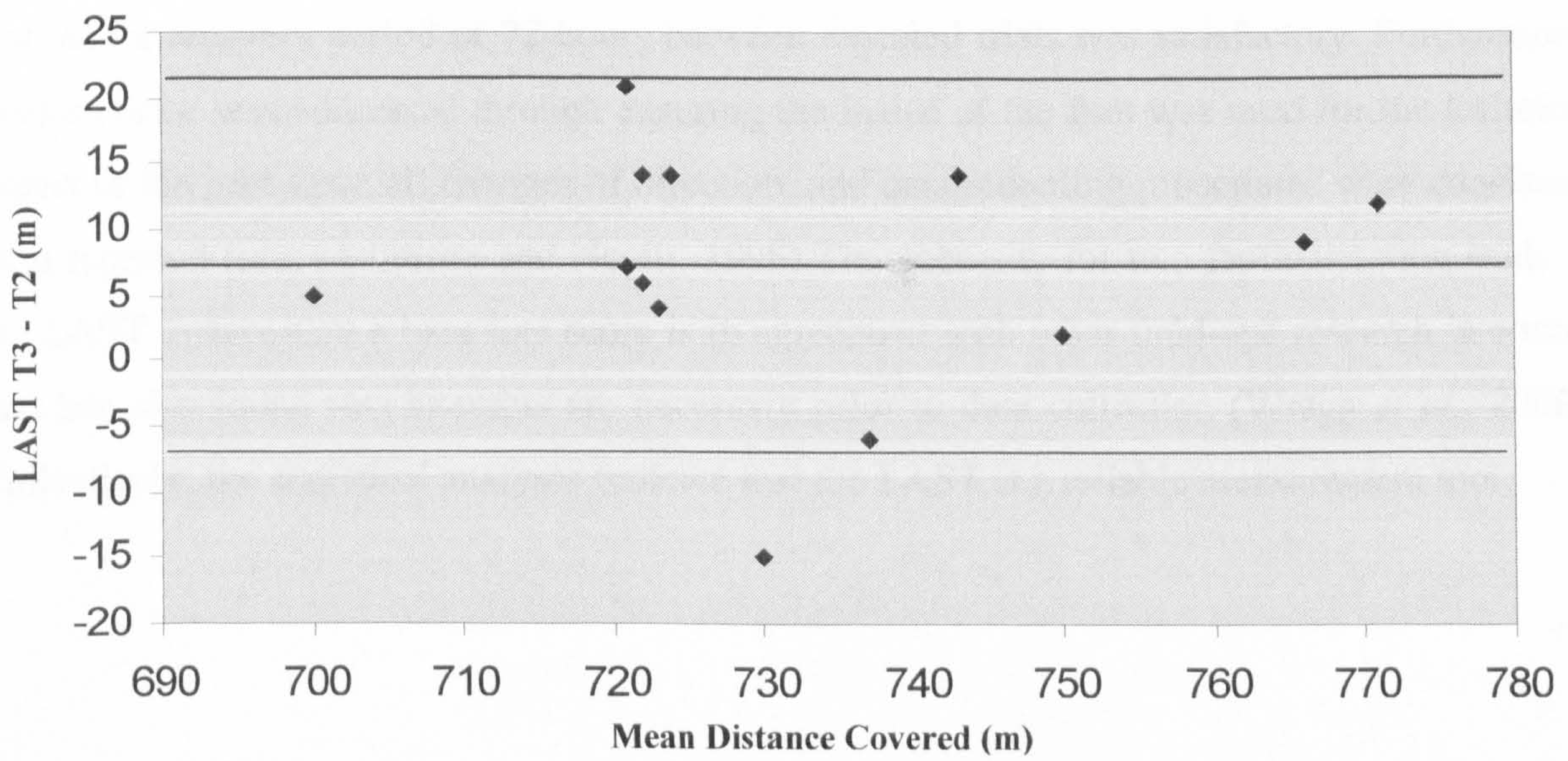


Figure 8. Bland-Altman Plot displaying the upper and lower limits of agreement for the LAST.

7.7 Discussion

In practice the LAST was easy to administer, though a minimum of two people are required for its set up. The purpose of pilot work was to highlight and correct methodological flaws (Thomas and Nelson, 1996). During the LAST test-1 and test-2, it was clear that there were some erratic pacing strategies used by subjects, although these did not impair reliability of the test in a major way. To address this matter during LAST test-3, vocal time cues were given by the administrator of the LAST (10, 20, 30, 40, 50, 55 s). Furthermore, during the recovery period between time trial repetitions, there was a 30-s time call, a 10-s stand on the line, and 5, 4, 3, 2, 1-go vocal cues. However, the recovery cues were also modified as subjects anticipated the "go" signal and started running early. Therefore, following the 10-s stand on the line call, subjects began the next repetition upon a whistle blow! The aforementioned modifications were well received by the subjects with regards pacing strategies, and provided tighter control between repetitions of 60-s time trials.

The LAST was able to distinguish between the different physical abilities within the group with a 75-m range from the lowest to the maximum score. This observation suggests that the LAST is sensitive enough to separate various levels of anaerobic capacity within a relatively small sample size (Thomas and Nelson, 1996).

Post-hoc analysis of the repeated measures ANOVA, coefficient of variation, and intra-class correlation indicated that two attempts of the LAST markedly reduce systematic bias of the test, and a recovery period of 72-hours between repeated trials was satisfactory. Furthermore, random error was addressed through ensuring the inside of the foot was used for the technical aspect of the pass upon all changes of direction, and data recording procedures were consistent with repeated tests (Atkinson and Nevill, 1998) The necessity for two familiarisation trials of the LAST to ascertain a base line score is in agreement with other field-test research in soccer that has also found two attempts are necessary prior to data collcetion (Wragg *et al.,* 2000). Collectively, the statistical analyses indicate that the LAST is a reliable measurement tool.

The ratio of the limits of agreement equaled ± 2.5% or ±18 m, and based on the total means of LAST-test 3 (736 m), a difference of ±18 m was deemed to be an acceptable practical range, since it would allow around ±6 m for each separate 60-s time trial within the LAST. Statistical power is the capability of a test to detect a significant effect (Vincent, 2005). To evaluate the power of this LAST investigation, post-hoc calculations were performed using the 95% confidence interval from LAST trial 3; the necessary sample size was calculated as 11 subjects (Borenstein *et al.,* 1997). Consequently, the sample size (n=13) used in this investigation was found to be adequate and sufficient to detect any differences.

7.8 Limitations and recommendations of study

During LAST test 3, the protocol was slightly changed with the addition of vocal time cues during each 60-s time trial and recovery periods. These auditory additions to LAST procedures compromised formal reliability, nevertheless these modifications did facilitate pacing strategies of the participants and did reduced the degree of cheating via premature starts during the second and third 60 s time trials. Consequently, the changes reduce the amount of measurement error that may transpire within each 60-s time trial and provide tighter control of activity during the recovery periods

7. 9 Conclusion

High-intensity activity and fatigue are two central aspects of contemporary match play. The anaerobic capacity is a key factor in performing and recovering from repeated high-intensity bouts of play during a game. Traditional means of assessment of anaerobic capacity are at best only a basic descriptor and provide little practical value to soccer. The current choice of tests has for some time been highlighted as inadequate. The purpose of this study was to pilot and develop a soccer-specific anaerobic capacity test. Statistical analysis confirmed the LAST to be a reliable measurement tool. The total measurement error (ratio of LOA) was ± 2.5% and accepted by the author. Therefore, as the LAST was found to be reliable, a validity study of the LAST follows.

7. 9 Part B – Physiological responses and face validity of the LAST

7. 10 Introduction

Validity is the degree to which a test measures what it is supposed to measure (Thomas and Nelson, 1996). The blood lactate concentration is the most common indicator of the activation of anaerobic glycolysis. At high-intensity activity oxygen supply is limited, so the player relies upon the anaerobic energy systems ATP-PCr, and fast glycolysis to provide ATP at a fast rate. Glycolysis involves a series of 10 enzymatically-controlled reactions breaking down glucose and glycogen to molecules of pyruvate and then subsequently lactic acid. Buffering systems within the blood then convert lactic acid to lactate. Consequently, lactate accumulation reflects the balance between production and clearance, as well as the influence of relative exercise intensity (Bouchard *et al.,* 1991; Brooks *et al.,* 1995). Average blood lactate values taken during soccer matches have been observed between 4 to 6 $mmol.l^{-1}$ (Shephard, 1999). Yet, blood lactate values reported as an average may undervalue the significance of the anaerobic capacity in soccer match-play. The high blood lactate values observed on several occasions (~10 $mmol.l^{-1}$) in soccer games highlight the importance of anaerobic capacity during periods of play. Furthermore, increases in high-intensity running result in greater lactate concentrations (Bangsbo, 2003), and high-intensity running and rapid recovery have been identified as important parts of contemporary match-play (Mohr *et al.,* 2003).

There are no gold standards or specific criteria to demonstrate that a person has produced a maximal anaerobic effort, unlike $\dot{V}O_{2\max}$ that has several criteria. The following measures have been used to evaluate anaerobic capacity; mean power, total work, oxygen debt, peak muscle and blood lactate, and maximal accumulated oxygen debt (MAOD). The 30 s Wingate test is the most prevalent test used to examine an individual's anaerobic capacity (Gore, 2000). However, it has been found that the minimum duration to exhaust anaerobic capacity is 60 s for an all-out and 120 s for constant load tests (Medbo *et al.,* 1988; Withers *et al.,* 1991). Furthermore, the Wingate cycle test does not reflect the movement patterns (running and turning) within soccer, thus the specificity of the Wingate test with soccer players is questionable. The MAOD test entails supramaximal responses to treadmill running (Medbo *et al.,* 1988) but its relevance to intermittent exercise has not been examined and the test is no longer fashionable.

Anaerobic performance test scores have been found to be reproducible especially under controlled stabilized conditions (Bar-Or, 1987). The test name *Liverpool Anaerobic Speed Test* provides logical/face validity, an aspect of validity by definition (Thomas and Nelson, 1996). The soccer-based design of the LAST provides superior ecological validity in comparison to the Wingate Test and other laboratory tests..

The purpose of this study was to evaluate the degree to which the LAST procedure stimulated the activation of anaerobic glycolysis via peak blood lactate values. The criterion for validity of maximal anaerobic effort is 14.7 $mmol.l^{-1}$, the mean peak lactate value of ten investigations using various established anaerobic capacity protocols listed in Table XII. The ten studies were compiled from anaerobic capacity investigations using moderately trained subjects that were of a similar fitness level as the Army subjects employed within this investigation. The peak lactate concentrations presented in Table XII provide data from the most common tests of anaerobic capacity, in order to compare the physiological responses of the LAST. It is acknowledged that equipment used and timing of blood lactate collection would influence the final lactate values produced, and more formal validity work with regards direct cross-validation with each specific protocol is needed.

Table XII: Peak blood lactate in anaerobic capacity tests.

Ref.	(n)	(A= Age)	Physical Status	AC Test	Peak Lactate (mmol·l^{-1})
McArdle *et al*,. (1996)	10	-	College males (Varsity Athletes)	Katch Test	16-17
Sands *et al.*, (2004)	11	21.4	University Athletes	Wingate Test	15.1
				Bosco 60-*s* Jump	13.5
Bosco *et al.*, (1983)	-	-	Basketball Players	Wingate Test	15.4 ±2.1
Balsom *et al.*, (1992a)	7	21.4	Moderate Training.	Intermittent Sprint (15 *x* 40 m) (Rec. = 30 *s*)	16.8
Balsom *et al.*, (1992b)	7	27.6	Moderate Training	Intermittent Sprint	
	7	27.6	(15 *x* 40 m) (Rec. = 30 *s*)		17.2 ± 0.7
	7	27.6	(15 *x* 40 m) (Rec. = 60 *s*)		13.9 ± 1.2
	7	27.6	(15 *x* 40 m) (Rec. = 120 *s*)		12.1 ± 1.3.
Finn *et al.*, (2003)	5	-	Endurance	MAOD 22°C	14.7 ± 3.8
			Cyclists	MAOD 30°C 51% rh	14.4 ± 4.5

rec = recovery period

rh = relative humidity

- = information not reported by investigators

7. 11 Methods

7.11.1 Subjects for validity study

In this study, 22 males from various British military standard soccer teams were involved. The characteristics of the subjects were as follows:-age 24 ±6.1 years, height 1.79 ± 0.02 m, body mass 77.6 ± 4.2 kg. Approval was obtained from University Research Ethics Committee and all subjects volunteered to participate in the study.

7. 11. 2 Procedures for validity study

The location of the validity study for the LAST was an indoor sports hall, wet bulb temperature 18.8°C. The LAST was conducted throughout the day (08:00-18:00 hours) to accommodate work commitments of the subjects. All participants' heart rates were monitored during the LAST using the Polar Team System (Finland), in order to investigate potential criterion for the LAST (peak heart rate for each 60-s time trial within 90-95%HR_{max}) and standardize maximal anaerobic effort. The LAST was carried out with a maximum number of 3 subjects in each group to facilitate blood lactate collection in between discrete 60-s time trials within the LAST. Blood was collected on a electrode strip and analyzed using a Lactate Pro Analyzer, a valid and reliable measurement tool with a 3% CV (Pyne *et al.,* 2000).

Limitations of the Lactate Pro Analyzer are that it evaluates lactate concentrations from the finger, not directly at the main working muscles. Consequently, as there are differences between individuals in buffering capacities, two players may produce similar lactate values despite work intensity and lactate production being different (Bangsbo, 2003). Secondly, the Lactate Pro Analyzer has a limited range of measurement 0.8-23 mmol·l. Furthermore, Shimojo and co-workers (1993) found that the calibration curve for electrode strips for measuring lactate in whole blood was only linear up to 20 mmol·l in contrast with blood plasma. Also, blood samples with low hematocrit levels displayed higher lactate concentrations. The Lactate Pro-Analyzer was first calibrated using the calibration strips provided. Prior to performing the LAST, subjects washed their hands in warm-water and pre-test blood samples were collected from a finger of non-dominant hand. The finger was first cleaned with a Medi swab, then a small puncture was made; a fresh needle was used for each puncture. Only 5 ul of blood was required for the test and lactate results were produced in < 60 s.

The subjects then performed a standardised warm-up for 5 min (start of level 6 on the MSFT) (Ramsbottom *et al.,* 1988), and carried out a series of static and dynamic stretches (Table IX). The data were collected by a combination of other soldiers and army physical training instructors who were first informed on how to record data on the LAST sheets (LAST-reliability study). The LAST test was run and controlled by the head Physical Training Instructor and the author collected then analyzed all the blood samples. Following the completion of the LAST, subjects rested until heart rate reached within 10 beats.min^{-1} of the initial level (Evans and Reilly, 1980) then performed the MSFT to determine maximum heart rate and estimate $\dot{V}O_{2max}$.

7. 12 Statistics for validity study

Descriptive statistics were used to highlight the mean score and spread of data between the subjects via standard deviation, and contrast with relevant research. To investigate the relationship between total-distance covered in the LAST and lactate values, Pearson r correlation was used.

7. 13 Results of validity study

The descriptive statistics for the discrete and total distances covered in the LAST can be found in Table XIII; the difference between time trial-1 and time trial-3 provide a fatigue index and the min and max results highlight the range of anaerobic capacity performance within the subjects of the validity study. Peak heart rates produced by the subjects during the respective 60-s time trials involved in the LAST are located in Table XIV, and confirm that the intensity of all three 60-s time trials were conducted at the desired intensity and criterion for the LAST test (90-95% HR_{max}). The min and max heart rate responses are associated with the age range within the subject population. The progressive blood lactate accumulation following each 60-s time trial performed at 90-95% HR_{max} as well as peak blood lactate response to the LAST can be found in Table XV. The min and max scores show the range of blood lactate values produced with the subject group. The correlation between LAST total distance covered and blood lactate values was low ($r = 0.37$) and was not significant ($P = 0.91$) (Figure 9).

Table XIII: Distance covered (m) for the subjects during the LAST validity study.

	(N)	Mean	± SD	Min	Max
60-s Time-Trial 1	22	267	11	240	285
60-s Time-Trial 2	22	242	11	222	264
60-s Time-Trial 3	22	231	15	202	255
Total Distance	22	740	33	681	795

Table XIV: Heart rates (beats.min^{-1}) for the subjects during the LAST validity study.

	(N)	Mean	SD	Min	Max
Maximum Heart Rate	22	198	7	183	212
Resting Heart Rate	22	87	13	64	118
LAST					
Time Trial 1	20	185	10	169	199
Time Trial 2	19	185	9	171	198
Time Trial 3	20	184	10	171	200

Table XV: Blood lactate results (mmol·l^{-1}) for the subjects during the LAST validity study.

	(N)	Mean	SD	Min	Max
Pre LAST	22	1.3	0.4	0.8	2.3
Time Trial 1	22	6.6	3.6	2	15.7
Time Trial 2	21	15	3.1	9	20.6
Time Trial 3	20	16.6	2.1	11.4	21.4
3 min post LAST	20	16.8	2.5	9.9	21.3
Peak Lactate of 4 Values	22	17.6	2.1	11.4	21.4

Note: Peak Lactate Values = the highest lactate value recorded during the LAST test.

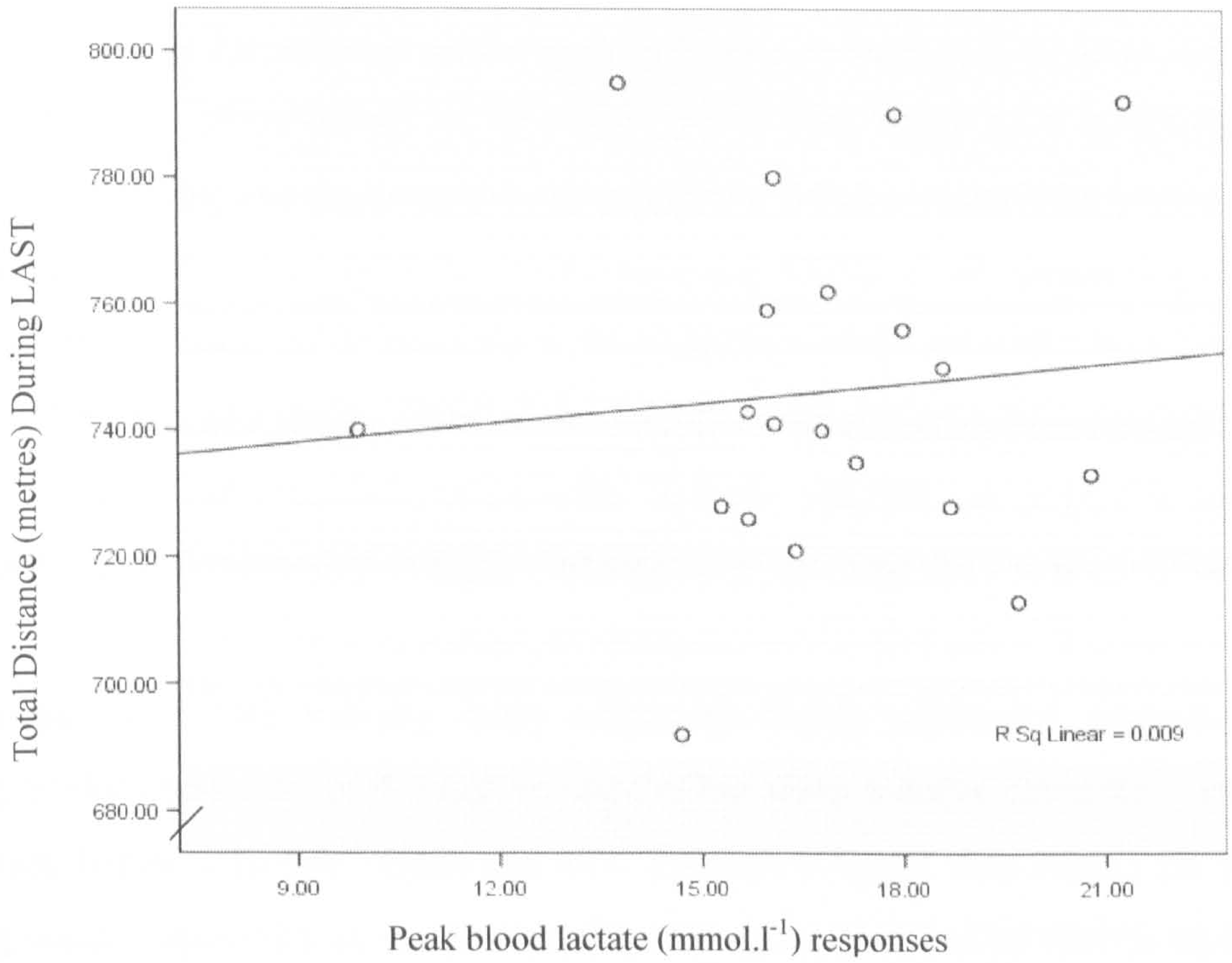


Figure 9. Total distance covered and peak blood lactate values during performance of the LAST.

7. 14 Discussion

There are no strict criteria to confirm that a person has produced a maximal anaerobic effort. So, in order to provide the practitioner with workable criteria guidelines of the LAST, each 60-s time trial repetition requires a relative peak heart rate within 90-95% HR_{max}. This LAST heart rate zone allows a workable range of 10 beats.min^{-1} and standardizes the relative intensity of the test. Having such criteria facilitates more objective comparisons between LAST performances, and enables practitioners to classify a test as valid measurement. Bangsbo (2003) reported a relationship between heart rate and blood lactate level during a game. The greater the heart rates during the 5-min period prior to blood collection, the higher the subsequent lactate value during measurement. The LAST validity study indicated the mean heart rate for all three 60-s time trials of the LAST was equal to 93% HR_{max} (185, 185,184 beats.min^{-1}), respectively. Therefore, the heart rate values of the subjects of the LAST validity study were classified as a maximal anaerobic effort as the test results met the 90-95% HR_{max} criterion.

The correlation between total distance covered and peak blood lactate values was modest and these results were not in agreement with the findings of Karlsson (1971), with greater blood lactate vales for subjects with superior fitness as measured by total distance covered in the test. However, observations of Karlsson (1971) were based on a comparison of untrained and trained subjects, and there were no standardised criteria within their protocol to ensure that the relative intensity was equal for all the subjects. Furthermore, psychological, motivational, and physical tolerances of an elevated acidity are important factors for high-intensity anaerobic exercise (Baechle and Earle, 2000) that should be considered when contrasting performance data of untrained and trained participants. Trained subjects are generally more determined, enthusiastic, and accustomed to higher intensities of exercise than untrained individuals.

In contrast, the LAST validity study employed highly motivated subjects from a similar training background who performed the test at the same relative intensity. Therefore, the poor correlation between lactate values and total distance covered may reflect the subjects' current training status, especially as the test session was conducted out of season in June and several subjects had recently returned from a military operation.

It is possible that during this period of reduced activity following the soccer season, several participants may have experienced some form of detraining of peripheral adaptations that were developed during the previous competitive season. Mujika and Padilla (2000) have found increased lactate levels in association with a reduction of bicarbonate levels as well as greater post-activity acidosis in a standardised exercise task following acute detraining effects (<4 weeks). The reduction in alkaline resolves affects the muscle's ability to sustain force production during high power activities (Baechle and Earle, 2000). Such detraining effects may have influenced the collection of data located at the bottom right-hand side of figure 8, relatively high blood lactate values with below average total distances covered.

Conversely, the data positioned centrally high and left of figure 8, show that some trained subjects are capable of producing a greater total distance for a lower blood lactate concentration. Anaerobic training has been found to increase buffering capacity by 12-50% following 8 weeks of training (Sharp *et al.*, 1986). Additional influential peripheral adaptations to anaerobic exercise include the density of monocarboxylate transporter proteins (MCT) 1 and 4 that facilitate the flux of lactate and hydrogen ions across muscle membranes, and during intense exercise they help regulate the pH level of the muscle.

High-intensity endurance training even from a single bout has been associated with an elevation of MCT corresponding to a reduction in muscle lactate during activity (Green *et al.*, 2002; Carsten *et al.*, 2004).

Genetic endowment and the concentration of fast-twitch muscle fibres within the individual determine the upper limits of anaerobic capacity as measured by total distance covered, and ultimately distinguish the differences between subject performances of the LAST. Cheetham and co-workers (1985) found that sprint-trained athletes covered a greater distance and produced higher lactate concentrations in contrast to endurance trained athletes in high-intensity anaerobic activity. Fast twitch fibres have a high glycolytic capacity, are responsible for fast powerful movements and produce large amounts of lactate. Conversely, the slow twitch fib and other tissues of the body use the lactate produced as a source of oxidative energy (Anderson, 2000).

There is a lack of criteria to confirm that an individual has produced a maximal anaerobic capacity attempt, so the mean blood lactate value from 10 established anaerobic capacity test results (14.7 $mmol.l^{-1}$) was used as criterion for validity. The peak blood lactate concentrations taken during the LAST were 17.6 $mmol.l^{-1}$, indicating that the LAST is a valid indirect measure of anaerobic capacity.

High blood lactate values are connected to the rate of glycolytic ATP production (Nagesser *et al.*, 1994). Furthermore, the only protocol from Table XI that produced similar blood lactate values (17.2 $mmol.l^{-1}$) was also a high-intensity running test (Balsom *et al.*, 1992b). However, the administration of Balsom and cowokers' (1992b) intermittent sprint protocol takes a relatively long time for a single test with a squad of players, and requires electronic timing gates, which are also not typically available in many soccer clubs. Also, the LAST peak blood lactate values suggests that the number of repetitions, *work:rest* ratios, and the 60-s duration of each discrete time trial are all satisfactory.

7. 15 Conclusion

The options for suitable soccer-specific anaerobic capacity tests have been suggested as inadequate. This study attempted to address this matter, and found the LAST is a reliable soccer-specific anaerobic capacity test that requires two familiarization trials to decrease systematic bias. There are no direct criteria that are available to establish the validity of anaerobic capacity assessments, and numerous protocols use various *work:rest* ratios and durations.

The LAST design involved criterion of peak heart rate values within 90-95% HR_{max} for each of the three discrete 60-s time trails within the LAST using a 1:1 *work:rest* ratio. The lactate values produced from performing the LAST were contrasted against ten results from applicable studies, and found to produce greater peak blood lactate values exceeding the mean values of these investigations. This evidence suggests that the LAST is a valid indirect measurement of anaerobic capacity, and the work: rest ratios and duration chosen are suitable for stimulating adequate activation of anaerobic effort.

The LAST scores have the potential to assist in designing both general and soccer-specific conditioning drills. Individual training goals can be established using the player's greatest distance covered in a single 60-s time trial of the LAST. Therefore, each player's unique performance capacity can be incorporated within a squad environment rather than adopting a uniform approach of *"One shoe size fits all"* of training. The LAST is user friendly and suitable for both professional as well as amateur soccer teams. Further, the LAST can also be adapted to other sports such as rugby, Australian Rules football, Gaelic football, hockey and so forth, changing a soccer-specific push pass to the respective skills inherent to the relevant sport.

Chapter 4

Study 2: The influence of environmental changes on a battery of soccer-specific field tests

8.0 Introduction

It is preferable to conduct soccer fitness testing within a controlled setting. Such practice standardizes factors that may interfere with performance results, with particular reference to environmental surroundings. Many European top-class professional soccer clubs have indoor facilities with artificial grass, and such a regulated environment provides an ideal location to perform soccer-specific field tests all year round. Qatar is located in the Arabian Gulf, where the environment can at times be severe (Figure 10). Like many soccer clubs based in warm climates, Al-Ahli Sports Club Doha has no suitable or available indoor facilities to conduct performance tests. Therefore the players are tested outdoors; this predicament is typical of many worldwide soccer teams.

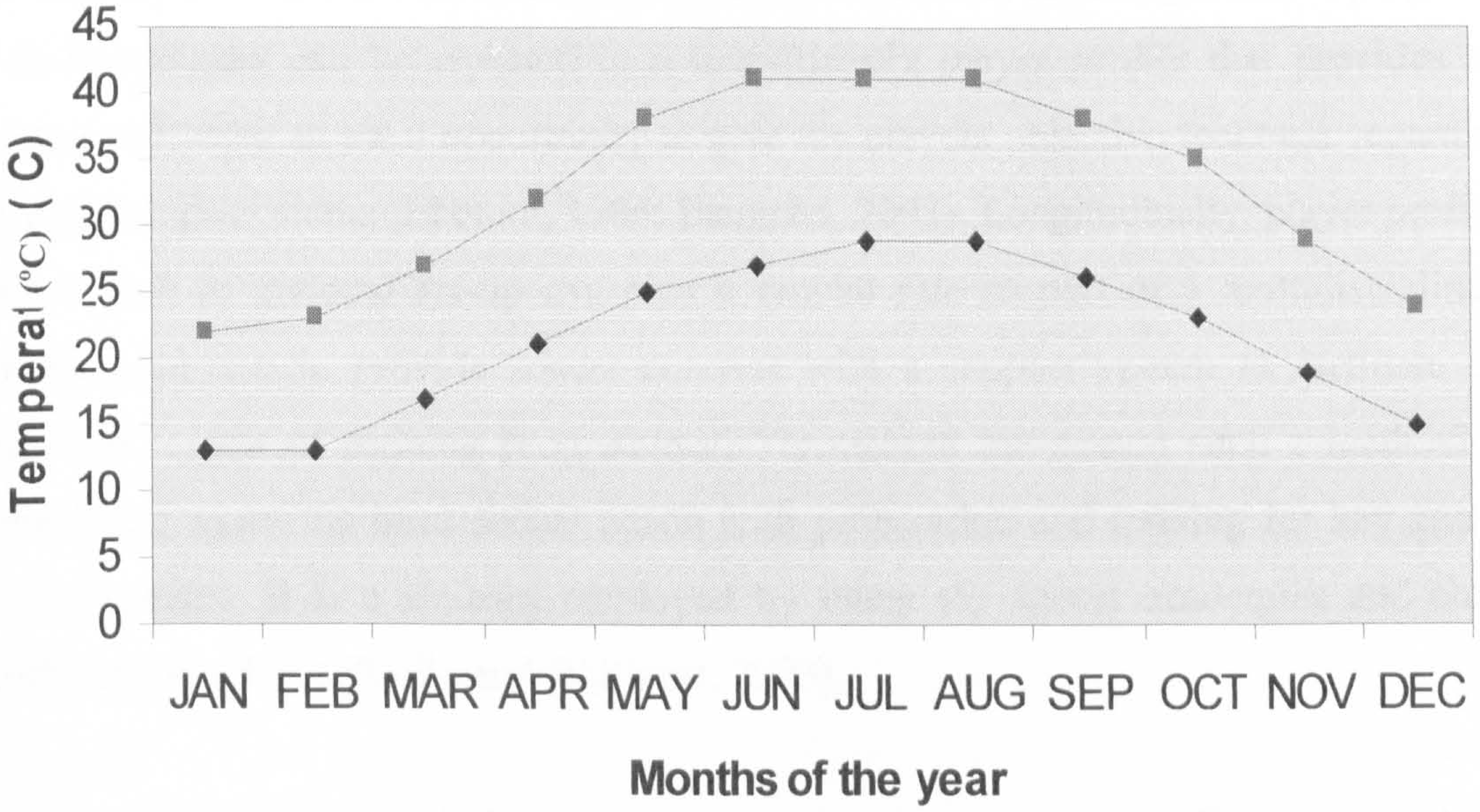


Figure 10. Average low and high temperatures in Qatar during the months of the year, *Modified from:* www.weather.com 2007.

Professional soccer coaches and players are keen to understand their teams' physical performance potential, and how this compares with measurements at different phases of the season, as well as with other standards of players from different leagues. The influence of environmental stress on discrete aspects of performance tests is unclear; climatic variations may distort results of performance assessments of the player within a season.

Therefore, it is relevant to know by how much environmental change influences performances in soccer-specific field tests. There is an extreme lack of data on how robust separate soccer-specific field tests are in different environmental conditions. A systematic approach to account for such climatic factors are an important aspect of data collection and analysis of performance tests conducted outdoors especially when investigating the influence of an intervention (*Ramadan*) on players' performances.

Fitness testing is a valuable part of monitoring contemporary professional soccer conditioning. The most important physiological factors that influence a player's match-play performance within a game can be evaluated using specific-soccer tests conducted outside the competitive environment (Ekblom, 1986). The concept of testing professional soccer players' physiological ability has been established for many years (Thomas and Reilly, 1979) and a basic test model for soccer was provided by Ekblom (1986) designed to be used by all coaches with a focus on specific endurance, sprinting, and jumping. The test battery results can be reported in a user-friendly *player profile* that provides the coaching staff with an ideal opportunity to give the players objective feedback regarding their physiological status (Ekblom, 1986; Bangsbo, 2003). Longitudinally, player profiles within a club or national set-up can play a crucial role as part of a multidisciplinary scientific approach to provide soccer coaches with a support system to facilitate the design and review of training programmes. Throughout the season such a methodical approach can assist the head soccer coach with preparation and training for key games and tournaments. It is a strategy employed by many top soccer academies and clubs globally in some form (Reilly and Williams, 2003).

Many of the detrimental influences on exercise in extreme conditions have been associated with hyperthermia as well as dehydration. Separately and combined, these factors can severely hinder performance (Montain and Coyle, 1992; Sawka and Montain, 2000). Morris and co-workers (1998) noted a 22% reduction of high-intensity running during hot - 30.0 ± 0.4°C (9678 ± 852 m) in comparison with moderate temperatures of 20.8 ± 0.6°C (12291 ± 218 m). There was no difference in dehydration, perceived exertion (RPE), lactate or ammonia concentration. However, in the hotter condition water consumption was almost doubled. The reduction in performance was associated with a high body temperature in the hot surroundings. Kenefick and colleagues (2002) investigated endurance athletes with 4% body mass hypohydration in ambient temperatures (22°C, relative humidity 45%).

Lactate threshold occurred at a significantly lower absolute exercise $\dot{V}O_{2max}$ in comparison with a euhydrated state. There was no difference in heart rate (%HR_{max}) at lactate threshold, and there was a significantly lower final blood lactate concentration. During a dehydrated state, the accompanying hypovolaemia reduces stroke volume and consequently the amount of blood circulated around the body per heart beat. Therefore, in order to carry out an absolute workload similar to a euhydrated state, the heart must beat faster to deliver the necessary oxygen and nutrients to the muscle, and remove waste products from the circulation. As a result, dehydration causes heart rates to be amplified at an absolute work load (Bangsbo, 2003).

The effects of the combination of thermal stress and dehydration on soccer players can be substantial. High-intensity efforts covered during a game were reported to decrease by 40% (400 m) at temperatures of 30°C in comparison with 20°C (Reilly, 2000). Therefore a key question is, whether or not the various soccer-specific field tests are affected in the same manner as games; since the time taken to complete the various fitness tests is much shorter in duration (<20 min) in comparison to the 90 min involved in soccer matches. Optimal ambient temperatures for endurance performance have been suggested to be around 10-16 °C (Maughan and Shirreffs, 2004; Reilly and Waterhouse, 2005). Furthermore, the effects of the environment on short duration activity may contrast with endurance performance. Warm surroundings may even be helpful in powerful activities such as in jumps and sprints (Maughan and Shirreffs, 2004). A rise in muscle temperature of 1-2°C can facilitate explosive performance, since the transmission of nerve impulses is accelerated, muscle metabolic processes are faster, and oxygen exchange from blood to active muscle tissue is quicker. Also, the player may be slightly lighter but retain the same power output with slight dehydration (Maughan, 2003; Reilly and Waterhouse, 2005).

With regards maximal anaerobic activity, Finn and colleagues (2003) found no real difference between lactate production (14.7 ± 3.8 versus 14.4 ± 4.5 $mmol \cdot l^{-1}$) during a maximum accumulated oxygen deficit (MAOD) test in 22°C and 30°C, respectively. The aforementioned investigation was performed within a laboratory; conversely when tests are conducted in a natural environment heat loss via radiation is possibly less effective, and may even be a source of heat accumulation via surroundings or direct effect of solar radiation. Temperatures within Qatar are typically higher than the 30°C often reported within the literature for related environmental studies of exercise in the heat, and at times greater than the upper limits of 35°C recommended for heat acclimatization processes (Maughan and Shirreffs, 2004).

The environmental surroundings have the potential to be debilitative for some and possibly beneficial for other aspects of fitness testing. There is a lack of previous research investigating soccer-specific field tests and environmental conditions. Therefore, the purpose of this study was to investigate how robust the discrete soccer-specific field tests are that potentially would be used for the main focus of this thesis, the influence of intermittent fasting during Ramadan on soccer-performance potential.

8.1 Methods

8.2 Subjects

In this study 42 students from Doha College (Qatar) GCSE P.E groups were involved, 16 females and 26 males. The characteristics of the subjects were as follows:- age 15-16 years, height 1.72 ± 0.08 m, body-mass 63.8 ± 16 kg. Approval was given from the University Research Ethics Committee, and all subjects volunteered to participate in the study.

8.3 Soccer-specific battery of tests

The battery of 16 soccer-specific fitness tests that have been selected were designed around a combination of the assessment model proposed by Ekblom (1986), and the soccer-fitness components highlighted by Bangsbo (2003) (Table XV). The theoretical basis for the tests was provided in the literature review Chapter-1.

Table XVI: Battery of soccer-specific field tests.

Physiological Fitness Component of Soccer	Test	Reference
1. Aerobic Power	20-m-Multisatge Fitness Test (Volitional Exhaustion)	Ramsbottom *et al.* (1988)
2. Sub-Maximal Aerobic	Yo-Yo Intermittent Recovery Test (9 min)	Krustrup *et al.* (2003)
3. Hybrid Aerobic/Anaerobic	Yo-Yo Intermittent Recovery Test (Volitional Exhaustion)	Krustrup *et al.* (2003)
4. Anaerobic Capacity	Liverpool Anaerobic Speed Test (LAST) (Almost maximal 90-95%)	Wilson *et al.* (2006) (Unpublished study-1)
Anaerobic Power –vertical plane		
5. Concentric power	Rocket Jump	Ekblom (1994)
6. Lower limb eccentric/ concentric-power	CMJ (No Arms)	Ekblom (1994)
7. Vertical height jump	CMJ	Ekblom (1994)
Anaerobic Power – horizontal plane		
8. Concentric power	SBJ	Reilly (1990)
9. Dynamic power-single limb	10-m Single leg Hop left	Roi *et al.* (2003)
10. Dynamic power-single limb	10-m Single leg Hop left	Roi *et al.* (2003)
Speed		
11. Short sprint	10-m Sprint	Studwick *et al.* (2002)
12. Long sprint	30-m Sprint	Studwick *et al.* (2002)
13. Dynamic start sprint	20-m (flying sprint)	Ekblom (1994)
14. Backward speed	10-m Backward sprint	Wilson *et al.* (2006) (Unpublished)
Agility		
15. 45° left emphasis	Zig Zag 20-m Left start	Buttifant and Graham (1999)
16. 45° right emphasis	Zig Zag 20-m Left start	Buttifant and Graham (1999)

The 20-m Multi-Stage Fitness Test (MSFT) (Ramsbottom *et al.,* 1988) was used to estimate $\dot{V}O_{2max}$. It is a field test that has many soccer-specific aspects and has been shown to have a strong significant correlation when cross-validated with a gold standard inclined treadmill test for maximum oxygen uptake (Aziz *et al.,* 2005). The MSFT equipment (Ramsbottom *et al.,* 1988) was calibrated prior to use as per supplier's directions via a stopwatch and a standardised 60-s intermittent bleep. The author directed the MSFT; subjects ran continuous 20-m shuttles in time to the bleeps from a CD that was played on a portable music system. The MSFT was performed until volitional exhaustion or failure to keep pace with three continuous bleeps. A non-participating student noted the shuttle and level number in accordance with the $\dot{V}O_{2max}$ score sheet, and the head P.E. teacher recorded the final shuttle and level number reached of each individual (see Appendix 1).

The Yo-Yo Intermittent Recovery Test level 1 (YYIRT) (Krustrup *et al.,* 2003) test provides an evaluation of a combination of energy systems (aerobic/anaerobic) that reflect the demands of soccer. It has also been found sensitive enough to detect changes in fitness of players with a similar $\dot{V}O_{2max}$ at sub-maximal time points of 6 and 9 min, as well as at maximal effort. The YYIRT (Krustrup *et al.,* 2003) equipment was calibrated prior to use according to supplier's instructions, via a stopwatch and a standardised 60-s intermittent bleep. The author directed the YYIRT, subjects ran intermittent shuttles 2 x 20 m in pace with bleeps from a tape played on a portable cassette player; following each run there was a 10-s active rest that involved a slow jog over 5 m. The YYIRT was performed until volitional exhaustion or failure to keep up with two successive bleeps. A non-participating student noted the shuttle and level number in accord with the YYIRT score sheet, and the head P.E. teacher recorded the final shuttle and level number attained by each individual (see Appendix 1).

Anaerobic capacity was evaluated using the Liverpool Anaerobic Speed Test (LAST), which was found to be a reliable, valid, and practical measurement tool in Study-1 of this thesis. The 1-m distances between cones of each individual 25-m line were carefully measured during the LAST set-up. The stopwatch used to control the 60-s time trials and rest periods was first checked against the 1-min bleep calibration process of the MSFT (Ramsbottom *et al.,* 1988), to ensure accuracy of time keeping. The author directed and controlled the LAST; subjects performed a 60-s time trial at 90-95% effort back and forth over 25 m with a soccer-push pass at the end of each run to change direction. Heart rate analysis (Polar Team System, Finland) was used to confirm the subjects met the 90-95%HR_{max} criterion for the LAST (chapter 2).

The LAST involves three consecutive 60-s time trials interspersed with 60 s of passive rest. Vocal cues were given (10, 20, 30, 40, 50, 55 s) to assist with pacing strategies during each time trial; during the 1-min rest periods, subjects were directed to stand on the line and get ready for the next 60-s time trial at 45 s. A whistle was blown on the 60 s mark; this signified both the end of the rest period and start of the next 60-s time trial. For each 60-s time trial, data were collected by non-participating students or P.E. staff who ticked a box for each 50 m covered (Figure 5); when the 55-s vocal-time cue was given, the participant, nearest spotter, as well as data collector for that particular subject were instructed to get ready to note the distance of the last shuttle run, as per marker cone reached upon the whistle at 60 s. The aforementioned personnel then collaborated, and clarified the distance of that specific time trial. Following the test, distances from all three 60-s time trials were added together to provide an overall total distance and indicator of anaerobic capacity.

Power tests are broken down into different aspects of movement. Vertical power tests include rocket jump, counter-movement jump with no arm involvement (CMJNA), and the counter-movement jump with arms (CMJ) (Ekblom, 1994). The rocket-jump was performed with the knees in a flexed position, heels in full contact with the floor within a comfortable range of motion for the player, and this position was held briefly to facilitate the required isometric start. The Rocket-jump was then executed without any prior counter-movement to measure dynamic concentric power of the lower limbs.

The CMJNA was started from an upright position; feet were shoulder-width apart with the hands placed on the hips throughout the duration of the test. An initial counter-movement preceded the vertical jump, and the CMJNA indicated eccentric-concentric power of the lower limbs. The CMJ is a progression of the CMJNA, and involves the coordination and power of the upper limbs to the action. The CMJ start-position also requires the feet to be positioned at shoulder-width, but the arms were held loosely by the side and used to assist the jump. Vertical power was quantified using the jump mat of the Newtest Powertimer-300 series (Oulu, Finland), self-calibrating accuracy ±2 mm.

Static horizontal power was evaluated using the standing broad jump (SBJ). Toes were positioned touching the outside of a line used for pitch markings within the sports-hall or soccer-field; feet were placed roughly shoulder-width apart and arms were held loosely at the sides. The test started in an upright position, and a counter-movement dip preceded the horizontal jump. Following the SBJ, the subjects were required to hold their landing posture and the heel of the foot that was closest to the start-line was used to measure the distance of the jump against a tape measure that ran adjacent to the SBJ, similar to the long-jump procedure in field athletics. Failure to hold the landing was classified as a "no-jump", accordingly another jump was then made following a recovery period (≥ 1 min).

The times taken for dynamic horizontal power, speed and agility tests were recorded using the Newtest Powertimer-300 series (Oulu, Finland), self-calibrating accuracy 0.001 s (time measurement). Electronic photocells were attached to tripods at a standardised height of 1 m, and positioned at 0 m, 10 m and 20 m of the left-hand side of the speed and agility set-up. The start of 10-m single leg hop, speed, and agility tests began at 1 m behind the start line, in order not to break the beam of the photoelectric cells early (Figure 12 speed set up). To avoid an order bias in the 10-m single leg hop and agility tests, the sequence of trials between left and right sides was completed in the ABBA assignment procedure (Vincent, 1999) whereby a left side attempt was followed by two right side efforts, and finished with the second attempt at the left side (LRRL).

Dynamic horizontal power was evaluated using the single-leg hop (left/right) test over 10 m. To start the test, the foot of the non-involved leg was raised behind the body towards the buttocks to prevent contact with the floor, as well as ensure a static start. The arms were held loosely at the sides. The backward 10-m run was used to evaluate speed of backwards motion. The subjects started this test with both feet parallel 1 m behind the start-line; on command the subjects ran as fast as they could in a backwards direction looking over the right shoulder for safety.

The electronic photocells were set up so that one sprint provided data on 10 m, 20 m, and *flying* 10-m speeds (Figure 12). The 10-m sprint was used to evaluate acceleration (Ekblom, 1994); the 30-m test is applicable for evaluating a player's rate of acceleration to peak velocity (Verheijen, 1998). However, as facilitates within the school did not allow an indoor 30-m run, a 20-m sprint was used instead. Therefore, a flying sprint was conducted from a 10-m sprint start, and evaluated at 10 m only. Subjects were instructed to run beyond the distance required until the finishing gate located 2 m past the final electronic photocell; this procedure was to facilitate optimal times and prevent subjects decelerating prematurely as they approached the final timing gate located at 20 m. The subject positioned the preferred foot in the centre of two cones located 1 m behind the start line and on command sprinted at maximal effort.

The 20-m Zig-Zag test (left/right) (Buttifant and Graham, 1999) was employed to assess agility. The layouts of the agility cones can easily be accommodated within the set up for straight-line speed, and so smooth the transition of speed to agility assessments within the test session. The rules of the agility test are that only a clear run is accepted and so if a cone is hit, the subject must retake the agility run following a recovery period (≥ 1 min).

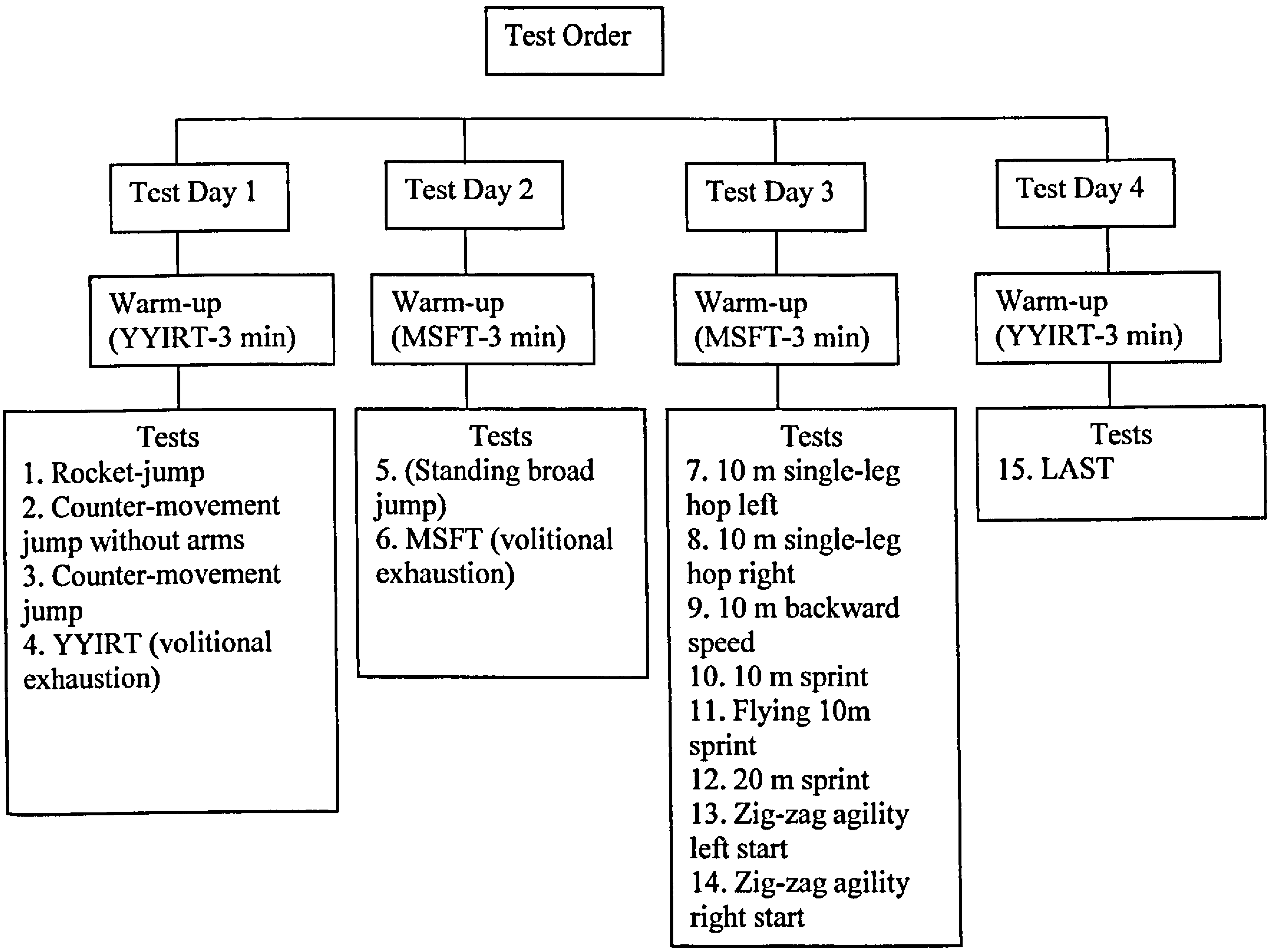
8.4 Soccer performance test order and administration

Students from Doha College (Qatar) completed the full battery of soccer-specific field tests to be potentially employed in Study-4, using a within-subjects repeated measures counter-balanced design. The students were divided into two groups based on their school physical education (P.E) class, to facilitate the conduct of this study and simultaneously accommodate the subjects' academic timetable. Physical education staff of Doha College administered the familiarisation trial for the full battery of performance tests in the weeks prior to this investigation and results produced from these respective tests contributed to the students' physical education coursework. Accordingly, a further familiarisation session of the LAST was conducted before this study (n =2) based on the findings of chapter 2.

To promote optimal performance, further familiarisation, and facilitate a smooth running of the test sessions, sub-maximal practice attempts of all performance tests were conducted on all days of testing, prior to data collection. The Multistage Fitness Test (MSFT) (Ramsbottom *et al.,* 1988) and Yo-Yo Intermittent Recovery Test (YYIRT) (Krustrup *et al.,* 2003) were employed sub-maximally for 3 min, as standardized warm-ups. With regards the Liverpool Anaerobic Speed Test (LAST), the students were separated into 3 sub-groups (n = 6/7) as per requirements of the test. The subjects of all sub-groups 1-3 then ran in turn, two lengths of the LAST course (25 m x 2) at roughly 70% effort with a soccer push-pass to change direction. For familiarisation of all vertical and horizontal static power tests, three sub-optimal practice jumps were performed, and for the 10-m single leg hop, speed as well as agility tests two sub-maximal runs were carried out.

For this study, group 1 firstly performed the full battery of soccer-specific field tests in ambient indoor temperatures (school sports-hall), and group 2 outdoors (school grass soccer-field). Both groups completed the full battery of soccer-specific field tests on 4 separate days. Accordingly, the groups then performed the battery of tests in the opposite environmental condition (group 1 outdoors and group 2 indoors) and the data collection was complete after 3 weeks, involving 8 days of testing.

All tests were conducted around the same time of day in accordance with the students' school timetable, between the hours of 10:50 to 12:50 hours. A minimum of 72 hours separated maximal aerobic and anaerobic tests to allow any residual fatigue to dissipate. During the tests all subjects wore the same garments for indoor and outdoor test sessions, as P.E. uniform was mandatory. Prior to all test administration and following the controlled warm-ups of 3-min for the MSFT (Ramsbottom *et al.*, 1988) or YYIRT (Krustrup *et al.*, 2003), joint-mobilisation, static and dynamic stretches were conducted (Table XI, Study-1). A flow diagram and brief description of test day order, set-up and administration will now follow:



YYIRT = Yo-Yo Intermittent Recovery Test

MSFT = Multi-Stage Fitness Test

Figure 11. Flow diagram of test order for study 2.

All test sessions were structured exactly the same for both indoor and outdoor conditions. Test session one was set up as per Figure 12, the day began with a standardised sub-maximal warm-up YYIRT for 3 min (Krustrup *et al.*, 2003) followed by stretching (Table XI), performance tests conducted were:

Vertical power:

1. Rocket Jump
2. Counter-Movement Jump Without Arms
3. Counter-Movement Jump

Aerobic/Anaerobic – high-intensity intermittent endurance:

4. Yo-Yo Intermittent Recovery Test- volitional exhaustion (Krustrup *et al.*, 2003)

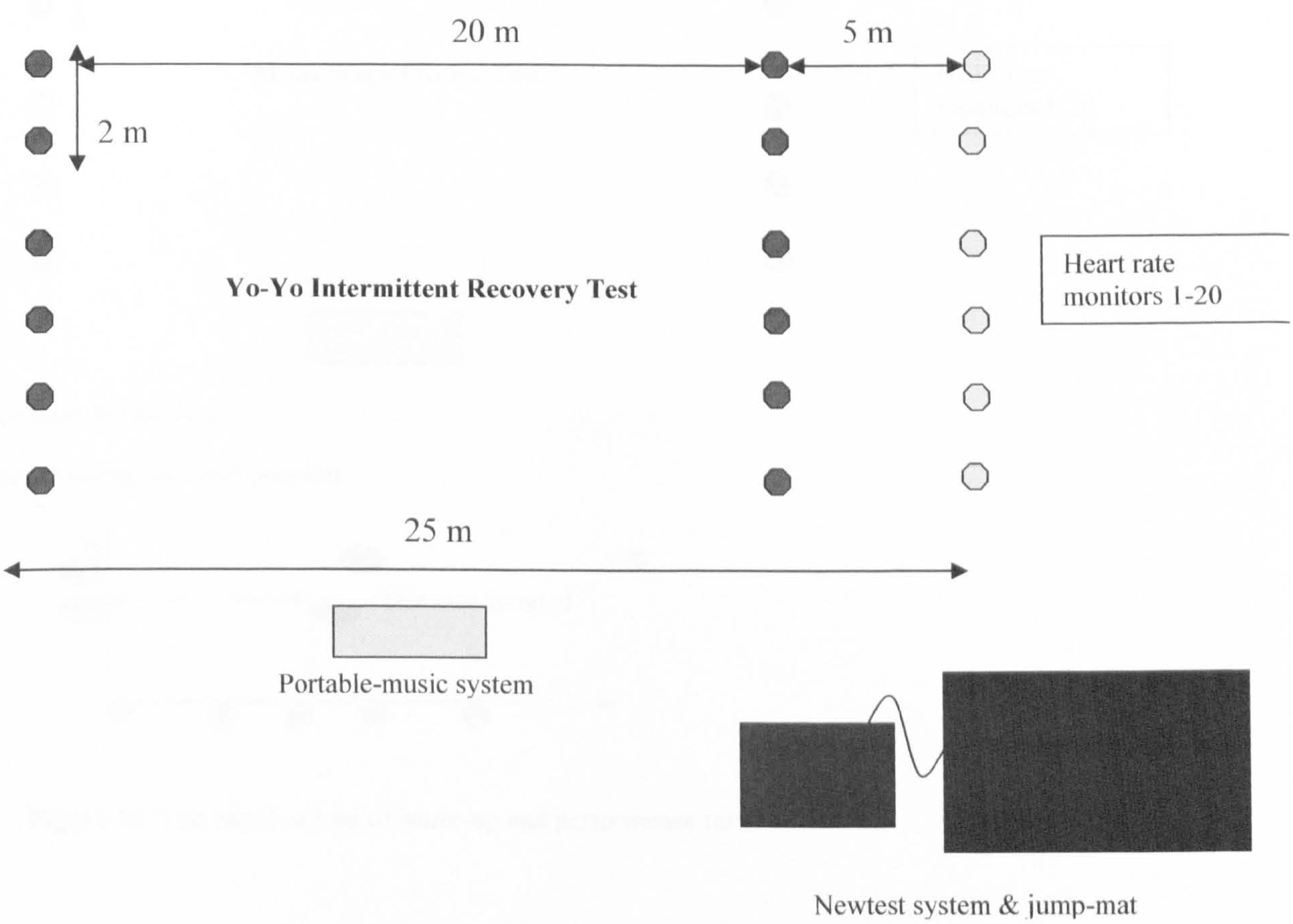


Figure 12. Test day-1, set-up of warm-up and performance tests.

The layout for test session two was as per Figure 13, the standardised sub-maximal warm-up was the MSFT (Ramsbottom *et al.*, 1988) for 3 min followed by stretching Table XI; the

performance tests conducted were:

Horizontal power (static)

1. Standing Broad Jump (SBJ)

Aerobic power

2. Multi-Stage Fitness Test to volitional exhaustion.

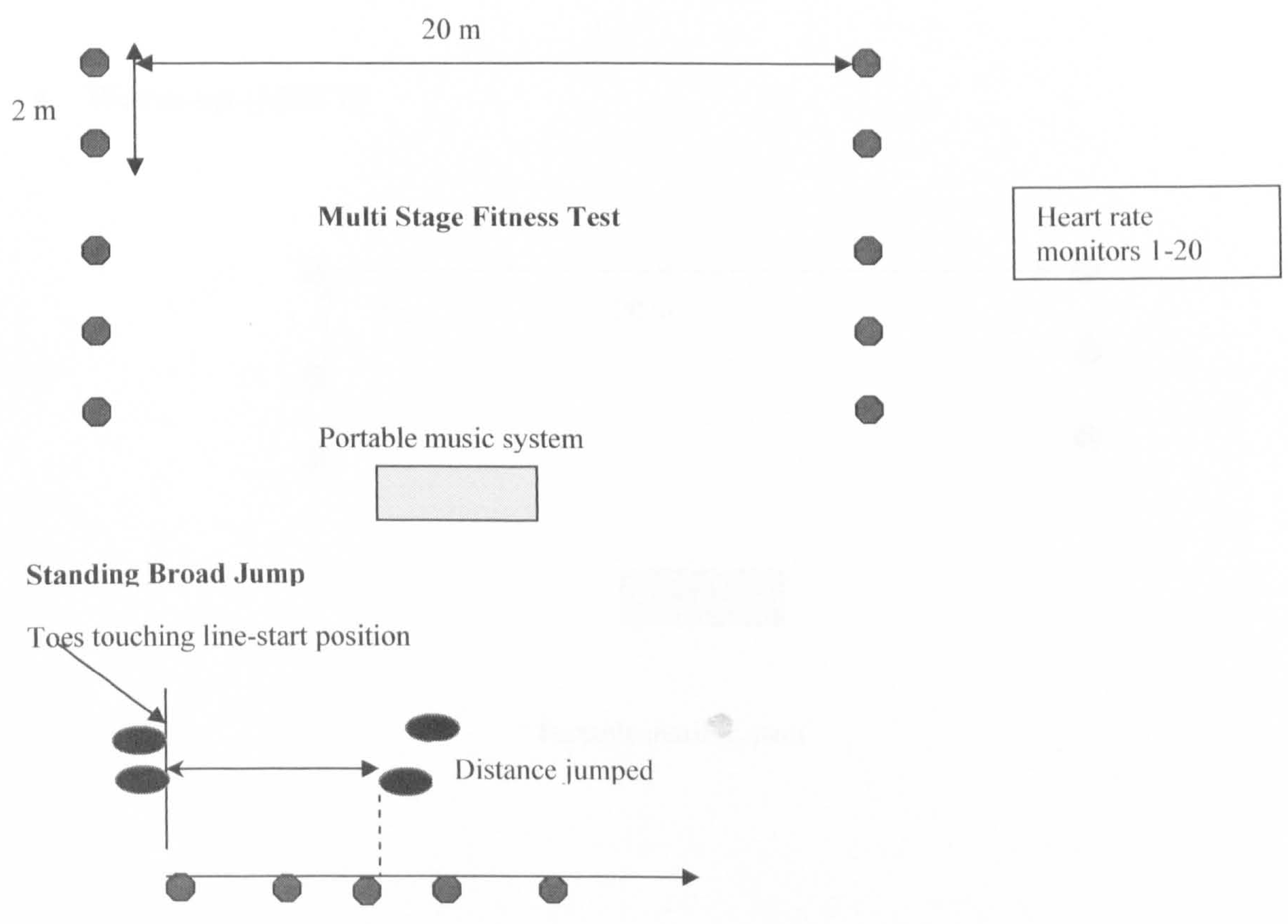


Figure 13. Test day-2, set-up of warm-up and performance tests.

Test day three was organised as per Figure 12, the MSFT (Ramsbottom *et al.*, 1988) was employed as the sub-maximal warm-up for 3 min followed by stretching Table XI; the performance tests conducted were:

Horizontal power (dynamic)

1. 10-m Single Leg Hop –left/right

Speed

2. Backward speed 10 m
3. Speed – 10 m, "flying" 10 m 20 m

Agility

4. Agility left/right 20 m

- **Warm-up (MSFT)**

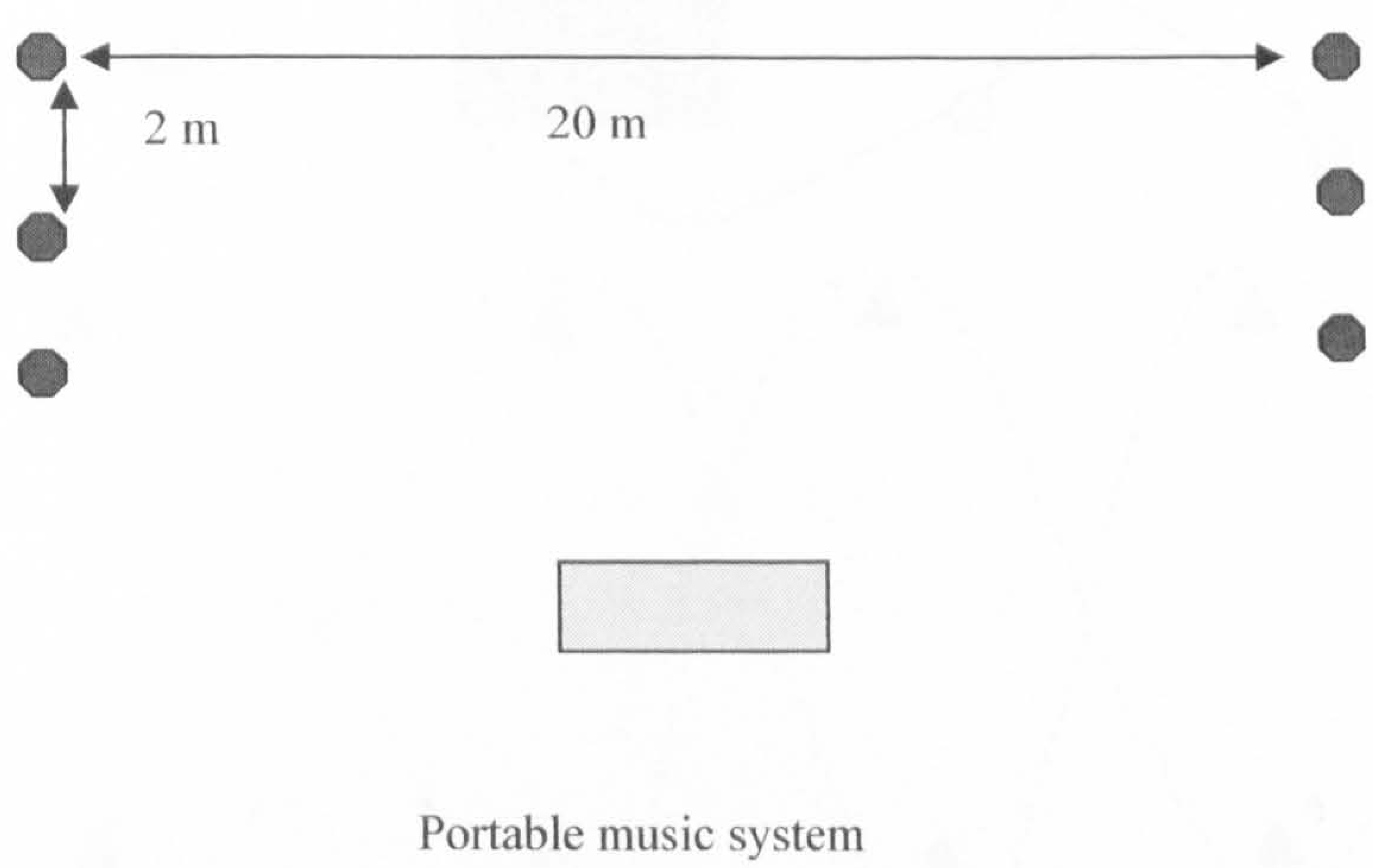


Figure 14a. Test day-3, set-up of warm-up

- **Speed-set-up**

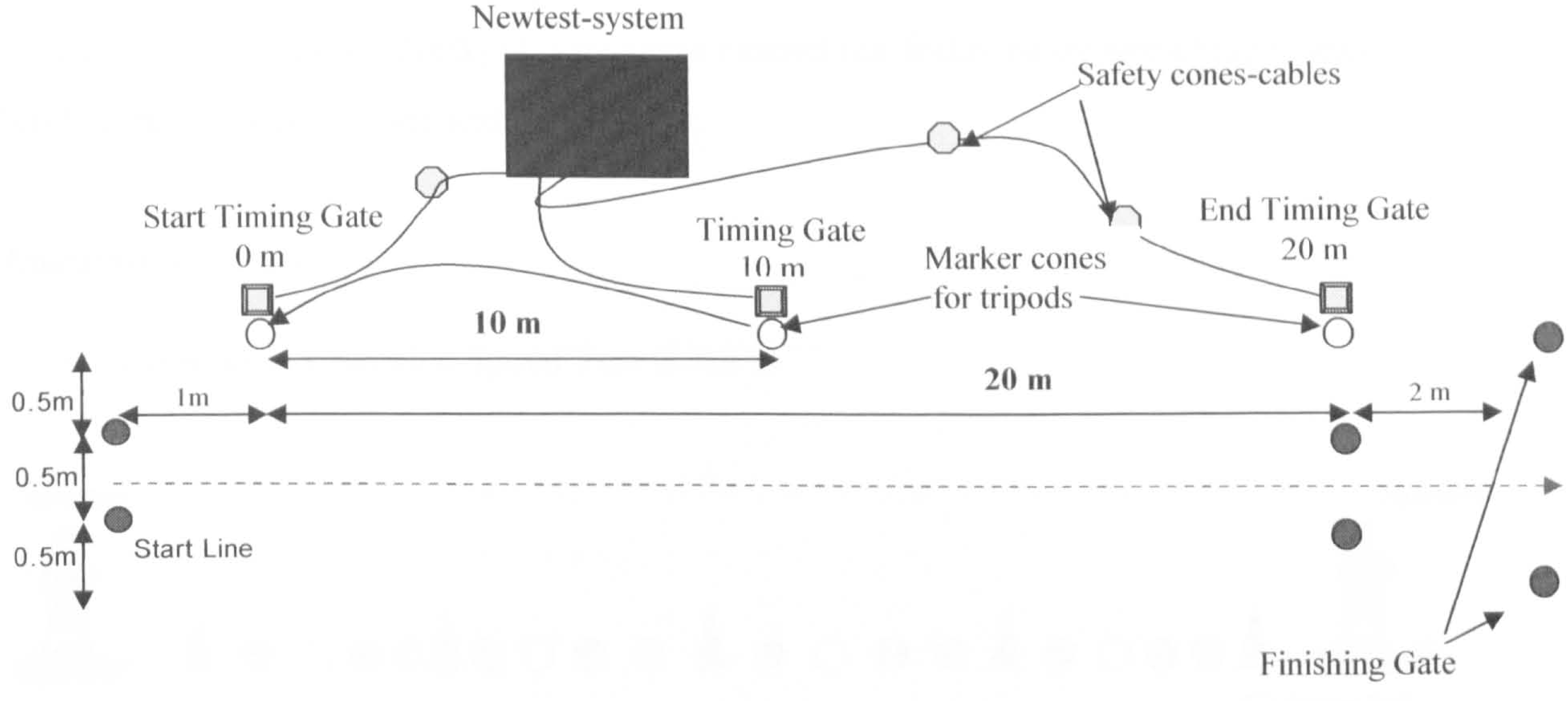
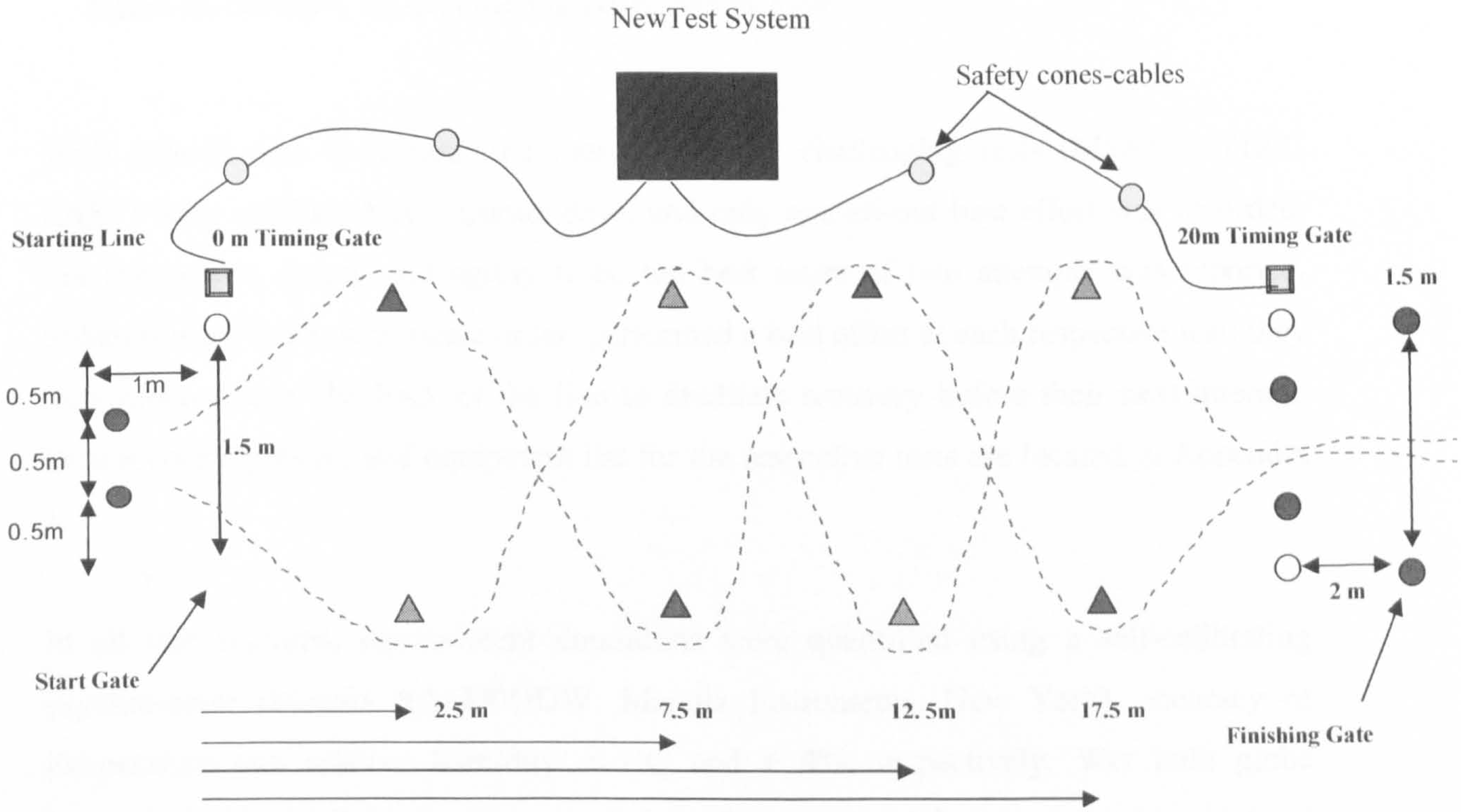


Figure 14b. Test day-3, set-up of speed performance tests

- **Agility Layout**



Key:
---➜ Left start 1st & 4th run.
---➜ Right start 2nd & 3 rd run.

Figure 14c. Test day-3, set-up of agility performance tests.

The plan for test day four was as per Figure 13, a controlled sub-maximal warm-up YYIRT (Krustrup *et al.*, 2003) of 3 min was carried out followed by stretching (Table XI) before the performance test, which was:

Anaerobic capacity

1. Liverpool Anaerobic Speed Test (LAST)

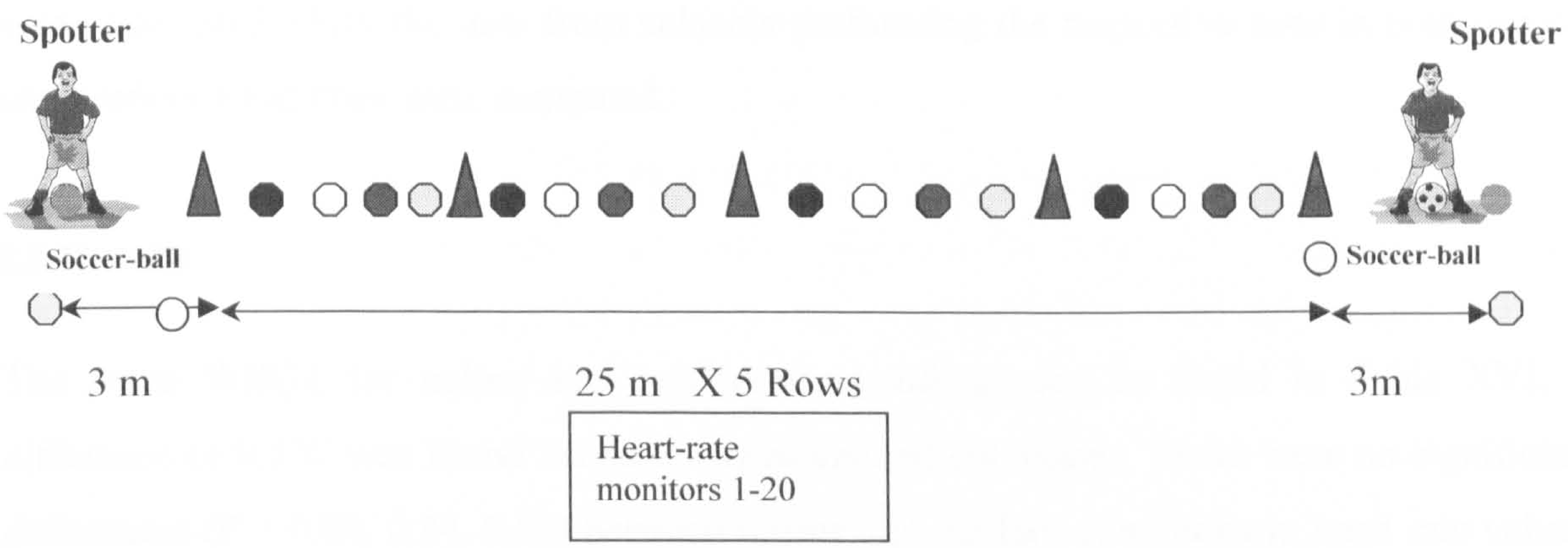


Figure 15. Test day-4, set-up of warm-up and performance test.

With regards data collection, the most physically challenging tests (MSFT, YYIRT, LAST) were conducted on separate days, and only one all-out best effort was recorded. For the power, speed, and agility tests, the best score of two attempts was reported. Subjects were lined up in name order, performed a best effort at each respective test; they then proceeded to the back of the line to facilitate recovery before their next attempt. Data recording sheets and equipment list for the respective tests are located in Appendix 1.

In all test sessions, environment conditions were quantified using a self-calibrating psychrometer (Mannix SAM99ODW, Mannix Instruments, New York), accuracy of temperature and relative humidity ± 1°C and ± 4%, respectively. Wet bulb globe temperature (WBGT) was used as an index of environmental stress, as it is calculated from measures of ambient temperature, relative humidity, and radiant heat (McArdle *et al.*, 1996). Wind speed was recorded using a self-calibrating anemometer (Skwatch Xplorer, Instruments Direct Services-Coalville, Leicestershire), precision ± 3%. Both WBGT and wind measurements were based on a mean time over 10 min at the start of testing.

8.5 Statistical analysis

Descriptive statistics were used to highlight the mean value and standard deviation. To investigate statistical differences between the soccer-specific battery of tests conducted indoor and outdoors, paired sample t-tests were used. . As the participants involved were both male and female, total subject number (both genders) and separate genders (male and female) were examined. Significance level was set at $P \leq 0.05$, and 95% confidence intervals were calculated. Only the data from subjects performing the respective tests in both indoor and outdoor conditions were computed.

8.6 Results

The mean WBGT for indoor and outdoor surroundings can be found in Table XVI, a difference of 9.5°C was found between environmental conditions. There were no significant differences ($P = 0.89, 0.84, 0.53$) between indoor and outdoor conditions in heart rate values for the estimated $\dot{V}O_{2\max}$ MSFT, YYIRT, and LAST (Table XVII and Table XVIII).

Table XVII: Environmental conditions for indoor and outdoor test sessions.

		Wet-Bulb Glob Temperature			Wind Speed
Location	(N)	Mean	SD	SE	$m.s^{-1}$
Inside	8	16.8	1.1	0.39	-
Outside	8	26.3	1.4	0.49	2.9

Table XVIII: Heart rate values ($beats.min^{-1}$) for MSFT, YYIRT during indoor and outdoor tests.

	Max Heart Rate		Indoor (WB-GT16.8 °C)		Outdoor (WB-GT26.3°C)		P-Value
	Mean	SD	Mean	SD	Mean	SD	
MSFT	203	10	203	10	200	12	0 .886
YYIRT	203	10	197	9	197	11	0 .842

Table XIX: Heart rate values($beats.min^{-1}$) for the LAST in indoor and outdoor assements.

	Max Heart Rate		Time Trial-1 Mean SD	P-Value	Time Trial-2 Mean SD	P-Value	Time Trial-3 Mean SD	P-Value
LAST (Indoor)	203	10	190 (8)		192 (5)		193 (7)	
LAST (Outdoor)	203	10	190 (7)	0.683	194 (6)	0 .775	196 (8)	0 .525

The means and standard deviations of the soccer-specific tests for the total subject number (both genders), as well as seperate male and female subjects can be found in Table XIX. There was no signifcant difference between indoor and outdoor conditions in estimated $\dot{V}O_{2\max}$, ananerobic capacity (LAST), vertical power, horizontal power, 20-m sprint, "flying" 10-m sprint, backwards 10-m speed, as well as agility (left and right) values across all data analysis.

There was a significant difference in YYIRT for both genders, male, and female subjects (P = 0.001, 0.001 and 0.003), respectively. The decrease in YYIRT performance conducted outdoors was roughly 1 min in time, and corresponded to reductions of total distance covered of 125 m, 132 m, and 112 m, for both genders, male, and female subjects, respectively. Sprint time over 10 m, was also significantly different for combined gender and separate male subjects (P = 0.049 and 0.001, respectively). However, 10-m sprint time for the females was not significantly different (P= 0.057) (Table XIX).

Table XX: Soccer-specific battery of test combined gender results Indoor *versus* Outdoor.

Both Genders:		Inside (WB-GT 16.8 °C)			Outside (WB-GT 26.3°C)			
Test	**(N)**	**Mean**	**SD**	**95%CI Diff**	**Mean**	**SD**	**95%CI Diff**	**P-Value Sig**
1. MSFT ($\dot{V}O_{2\max}$) (ml.kg^{-1}.min^{-1})	34	38.8	± 8.1	(36.1 – 42)	38.6	±7.3	(36.1 – 41)	0.91
2. YYIRT (6-min)	-	-	-	-	-	-	-	
3. YYIRT (metres)	36	688	± 428	(549-827)	562	±350	(448 – 676)	0.001
4. LAST (metres)	27	646	± 88	(436502)	645	±8	(447 –512	0.9
5. Rocket Jump (cm)	37	32.9	±6	(31–35)	32.8	± 7	(31–35)	0.93
6. CMJNA (cm)	37	33.5	±7	(31–36)	34	± 7.5	(31–37)	0.78
7. CMJ (cm)	37	38.7	±8.1	(36–41)	39.4	±8	(37-42)	0.72
8. SBJ (metres)	34	1.95	±27	(185-201)	1.99	±3	(188–206)	0.48
9. 10 m SLHL (seconds)	31	2.71	± 0.4	(2.64–2.78)	2.87	±0.5	(2.75–2.90)	0.16
10. 10 mSLHR (seconds)	31	2.93	± 0.5	(2.75–3.11)	2.92	±0.4	(2.78–3.06)	0.97
11. 10 m Sprint (seconds)	29	1.80	± 0.1	(1.76–1.86)	1.91	±0.2	(1.85–1.97)	0.049
12. 20m Sprint (seconds)	29	3.31	± 0.2	(3.23–3.39)	3.4	±0.4	(3.27–3.53)	0.46
13. "Flying" 10 m (seconds)	29	1.50	±0.2	(1.44–1.56)	1.49	±0.3	(1.39–1.59)	0.81
14. Backwards 10 m (seconds)	32	2.69	±0.3	(2.58–2.8)	2.70	±0.3	(2.61–2.79)	0.95
15. 20 m ZZ Agility L (seconds)	31	4.8	±0.4	(4.67–4.43)	4.88	±0.3	(4.71–5.09)	0.35
16. 20 m ZZ Agility R	31	4.7	±0.4	(4.55–4.85)	4.90	±0.3	(4.80–5.00)	0.060

95%CI Diff = 95% Confiedence Interval for data collected inside and outside.

Table XXI: Male gender results Indoor *versus* Outdoor of soccer-specific battery of tests.

Male:		Inside (WB-GT 16.8 °C)			Outside (WB-GT 26.3°C)			
Test	**(N)**	**Mean**	**SD**	**95%CI Diff**	**Mean**	**SD**	**95%CI Diff**	**P-Value Sig**
1. MSFT ($\dot{V}O_{2max}$) (ml.kg^{-1}.min^{-1})	22	42.1	±7.4	(39–45.2)	41.6	±6.9	(38.7–44.5)	0.28
2. YYIRT (6-min)	-	-	-	-	-	-		
3. YYIRT (metres)	23	753	±484	(557–949)	621	±390	(462–779)	0.001
4. LAST (metres)	17	672	±87	(631–713)	668	±85	(611–705)	0.056
5. Rocket Jump (cm)	24	35.4	±5.5	(33-38	35.5	± 5.1	(34–38)	0.456
6. CMJNA (cm)	24	37.1	±6.1	(35–39)	37.4	± 6.4	(35–40)	0.287
7. CMJ (cm)	24	42.7	± 6.3	(40–45)	43.3	±6.5	(41–46)	0.38
8. SBJ (metres)	22	205	±26	(194–216)	204	±25	(194–215)	0.651
9. 10 m SLHL (seconds)	21	2.53	± .28	(2.41–2.65)	2.59	±.30	(2.46–2.72)	0.228
10. 10 mSLHR (seconds)	21	2.65	±.30	(2.52–2.78)	2.70	± .35	(2.55–2.85)	0.378
11. 10 m Sprint (seconds)	19	1.76	±.12	(1.71–1.81)	1.81	± .11	(1.76–1.86)	0.001
12. 20m Sprint (seconds)	19	3.22	± .18	(3.1–3.33)	3.23	± .29	(3.10–3.36)	0.916
13. "Flying" 10 m (seconds)	19	1.45	± .11	(1.40–1.5)	1.46	± .13	(1.40–1.52)	0.130
14. Backwards 10 m (seconds)	22	2.60	±.32	(2.57–2.73)	2.58	± .27	(2.46–2.70)	0.565
15. 20 m ZZ Agility L (seconds)	21	4.64	± .27	(4.52–4.76)	4.68	±.30	(4.55–4.81)	0.375
16. 20 m ZZ Agility R	21	4.54	±.22	(4.45–4.64)	4.57	± .22	(4.47–4.67)	0 .090

95%CI Diff = 95% Confiedence Interval for data collected inside and outside.

Table XXII: Female gender results Indoor *versus* Outdoor of soccer-specific battery of tests.

Female:		Inside (WB-GT 16.8 °C)			Outside (WB-GT 26.3°C)			
Test	**(N)**	**Mean**	**SD**	**95%CI Diff**	**Mean**	**SD**	**95%CI Diff**	**P-Value Sig**
1. MSFT ($\dot{V}O_{2\max}$) (ml.kg^{-1}.min^{-1})	12	32.8	± 5.5	(27.8–37.8)	33.1	±4.5	(31–35.6)	0 .48
2. YYIRT (6-min)	-	-	-	-	-	-	-	
3. YYIRT (metres)	13	572	±289	(415–729)	460	±250	(324–494)	0.003
4. LAST (metres)	10	600	±72	(656–644)	594	±62	(555–633)	0.134
5. Rocket Jump (cm)	13	28.6	±4.3	(26.2–31)	28.7	±4.8	(26–31)	0.840
6. CMJNA (cm)	13	26.1	±3.6	(23.8–28.2)	27	± 3.2	(25.2–28.8)	0.037
7. CMJ (cm)	13	30.4	± 4	(28.2–32.6)	30.7	±3.9	(28.5–32.9)	0.479
8. SBJ (metres)	12	175	±16	(1.66–1.84)	176	±15	(1.71–1.89)	0.049
9. 10 m SLHL (seconds)	10	3.09	± .34	(2.87–3.31)	3.10	±0.40	(2.85–3.35)	0.638
10. 10 mSLHR (seconds)	10	3.5	± .23	(3.38–3.66)	3.4	± .22	(3.28–3.56)	0.086
11. 10 m Sprint (seconds)	10	1.90	± .09	(1.85–1.95)	1.98	± .14	(1.89–2.07)	0.057
12. 20m Sprint (seconds)	10	3.49	±.21	(3.36–3.62)	3.52	± .22	(3.38–3.66)	0.051
13. "Flying" 10 m (seconds)	10	1.62	±.19	(1.49–1.73)	1.67	± .13	(1.59–1.75)	0.108
14. Backwards 10 m (seconds)	10	2.91	± .32	(2.83–3.0)	2.95	±.14	(2.87–3.03)	0.068
15. 20 m ZZ Agility L (seconds)	10	5.15	±.34	(4.94–5.36)	5.08	±.25	(4.93–5.23)	0.093
16. 20 m ZZ Agility R	10	5.18	±.37	(4.95–5.41)	5.19	±.24	(5.04–5.34)	0.784

95%CI Diff = 95% Confiedence Interval for data collected inside and outside.

8.7 Discussion

The degree of environmental stress within this study was high (WBGT = 26.3°C) and within the ranges of the climatic surroundings experienced by Qatari soccer players during the months of September, October, and November, when the main investigation of this thesis was scheduled. Furthermore the mean difference between indoor and outdoor conditions (WBGT 9.5°C) was similar to temperature variations reported in previous work associated with heat stress and exercise (Morris *et al.,* 1998; Reilly and Waterhouse, 2005); this indicates that climatic surroundings between the two conditions in this investigation were appropriate. The WBGT also highlights the severity of the conditions experienced by Qatari soccer players.

There are no current guidelines or criteria regarding wind velocity during soccer-specific field tests outdoor; wind-speed is a factor for acceptance of world record performances (for sprints and horizontal jumps) at elite level such as, the Olympic games (≤ 2 $m.s^{-1}$). In one of the few studies that have reported wind speeds, Chamari and co-workers (2003) noted that wind velocity did not exceed 4.11 $m.s^{-1}$. In contrast, the maximum wind velocity recorded in this investigation was 5 $m.s^{-1}$ and the average was less 2.9 $m.s^{-1}$. In accordance with the Beaufort-scale 3.5 to 5.4 $m.s^{-1}$ has a value of 3, and classified as a gentle breeze (Met office, 2006). Based on weather reports (Doha, Qatar weather, 2006) a value below 5.4 $m.s^{-1}$ is a typical reflection of wind speed for this time of year especially inland. Whilst such wind conditions are favorable for speed assessments, it should be noted that wind plays a role in alleviating heat strain via convection (Roitman *et al.,* 1998). Therefore, it is essential that future work involving soccer-field tests outdoors, reports both wind speed as well as WBGT as an index of environmental surroundings, to facilitate more objective comparisons of soccer performance test data. This investigation focused on how robust the discrete tests within the soccer-specific battery are and the following discussion is based on the test order listed in Table XV.

Estimated $\dot{V}O_{2max}$

The criterion to confirm that $\dot{V}O_{2max}$ was attained was a maximum heart rate within 10 beats.min^{-1} of the age-predicted maximum (Siff, 2003). As the subjects were aged 15-16 years, the mean predicted maximum heart rate was (204-205 beats.min^{-1}). For both the indoor and outdoor 20-m shuttle runs ($\dot{V}O_{2max}$), maximum heart rates were within this range, 203 ±10 and 200 ±12 beats.min^{-1}, respectively. Therefore, both tests were classified as having produced valid $\dot{V}O_{2max}$ estimates. Further, these maximal heart rates are comparable with other reported values for this age group (201 ±8 beats.min^{-1}) (Billows *et al.,* 2003). There were no significant differences between the mean $\dot{V}O_{2max}$ values for indoor and outdoor conditions for the combined and individual gender analysis.

This finding suggests that there was no real difference in a $\dot{V}O_{2max}$ test score when performed indoor or outdoor in the reported conditions. The subject population was young (U15-16) and from a general background with an average fitness level of 38.8 ±8.07 ml.kg^{-1}.min^{-1}, and these results were similar to $\dot{V}O_{2max}$ values (39.7 ±12 ml.kg^{-1}.min^{-1}) found in state standard soccer teams of a similar age (15.6 ±1.02 years) playing in the USA (DeMello *et al.,* 2003). The average duration of the test for the Doha College students was roughly only 7 minutes (MSFT-level 7 shuttle 5). In contrast, during the familiarisation test sessions undertaken in the previous season, Al Ahli soccer players averaged estimated $\dot{V}O_{2max}$ values of only 51±4.2 ml.kg^{-1}.min^{-1} (MSFT-level 11 shuttle 4) corresponding to a difference of roughly 4 minutes in performance time from the Doha College students.

Following exercise producing a severe heat load, sweat glands are activated around 7 min, the extent that body temperature is then increased is determined by the intensity and the environmental conditions (Reilly and Cable, 1996); the MSFT is a progressive test and intensity is increased by 0.5 km.h^{-1} every minute (Ramsbottom *et al.,* 1988). Therefore, it is likely that environmental surroundings will have little meaningful difference on the MSFT conducted with Al Ahli professional players since, the aerobic power of the Al-Ahli players was below the measured values reported for elite soccer professionals 55-70 ml.kg^{-1}.min^{-1} (Shephard, 1999).

However, it is still not clear regarding how a hot and humid environment would influence professional soccer players at the highest echelon of aerobic power (Shephard, 1999) and capable of reaching a greater absolute intensity; naturally the duration of their estimated $\dot{V}O_{2max}$ tests would be longer and accompanied by a potentially greater increase in body temperature particularly, if cooling mechanisms from sweat are hindered by environmental conditions.

Yo-Yo Intermittent Recovery Test (YYIRT)

During the YYIRT level 1, heart rate values taken at 6 and 9 min have been used to provide an indication of sub-maximal performance (Krustrup *et al.,* 2003). The subjects failed to sustain the intensity of the test to 6 min, and so a sub-maximal aerobic comparison was not possible. The mean maximal heart rates of the YYIRT for both indoor and outdoor conditions reached the same values of 197 beats.min^{-1} (97% HR_{max}), thus both tests were accepted as valid measures of YYIRT performance. There was a significant reduction in total distance covered when the YYIRT was conducted outdoors despite; maximal heart rate values measured being equal (Table XVII) in both conditions.

The mechanisms for explaining differences in performance were beyond the scope of this investigation. However, as the subjects' attempts on the YYIRT were of a relatively short duration (around 4-5 mins), it is unlikely that dehydration occurred during this time frame and hindered performance. Body temperature may have been a contributory factor in the reduction in performance of the YYIRT, as by the time the subjects performed the test they would have been exposed to adverse hot surroundings (WBGT 26.3°C) for roughly 30 min. Furthermore, heat accumulation generated from the rapid energy production to facilitate the high-intensity demands of the YYIRT cannot be transferred to the air as effectively in the outdoor conditions, in comparison to the air-conditioned surroundings of the school sports hall! Intermittent exercise has also been found to stimulate greater core temperatures (0.3 °C) when contrasted to continuous exercise of a similar relative intensity (Ekblom *et al.,* 1971). The acute effects of exercise in a hot climate include an increase in heart rate, core temperature, perception of effort, and reduction in cerebral blood flow (Armstrong and Maresh, 1991).

A rise in temperature of the cerebrum area is a key factor in the aetiology of fatigue during sustained activity (Nybo *et al.,* 2002). Conversely, delaying core temperature via pre-exercise cooling strategies has been found to facilitate performance (Kay *et al.,* 1999; Datson *et al.,* 2007), highlighting the benefits of addressing the potential detrimental consequence of an increase in body heat. Other possible causes of the reduction of YYIRT performance may be associated with oxygen delivery mechanisms, since none of the anaerobic tests were negatively affected in the heat. Nonetheless, the evidence from this study suggests a WBGT in the region of 26.3°C has a considerable negative influence on maximal performance in the YYIRT. This finding is consistent with the detrimental effects of heat that have been observed during high-intensity activity (Morris *et al.,* 1998; Reilly, 2000).

Anaerobic capacity

The criteria for the LAST (90-95% HR_{max}) for all three 60 s time trials were met, and so accepted as valid measurements for both indoor and outdoor assessments of anaerobic capacity (Table XVIII). There were no statistical differences in anaerobic capacity between the two climatic conditions; this observation supports the findings of Finn and colleagues (2003) who also reported no difference in anaerobic performance between different environmental conditions of 20°C and 30°C in a laboratory setting. Thus, this present observation suggests that LAST is robust and variation of a hot environment has little meaningful influence on its performance.

Vertical and horizontal power

There were no significant changes between indoor and outdoor conditions in any of the vertical power jumps. The performance scores of the Doha College students for rocket jump, CMJNA, and CMJ were 32.9 ±6.2, 34±7.5 cm, and 39.4±8.39 cm respectively. These results are below U-15 Premier League Academy players whose equivalent scores have been observed at 36.5 ±5, 39.9 ±4.9 and 42.3±5.7 cm (unpublished observations for the English Football Association).

There was no significant variation in static horizontal power, the average score ranged from 1.95- 1.99 ± 0.26 m. Dynamic horizontal power, as measured by 10-m single leg hop left and right, were also not significantly different between the two environmental conditions. Therefore, in accordance with the other power tests of this investigation, horizontal power does not seem to be affected by environmental changes, and any discomfort associated with exercise in the heat did not impair performance. The most likely explanation for no change in power test performance is that the requirements of the activity are short in duration (<3 s) and energy is supplied by the immediate alactic system, phosphocreatine (Hultman *et al.*, 1983). Consequently core temperature is unlikely to rise to a debilitating level through carrying out power tasks outdoors, and the moderate temperatures recorded indoors would also be favourable for power performances. Furthermore, it is highly likely that the subjects were in a euhydrated state when the power tests were conducted, and so dehydration was not an influential factor.

Speed and Agility

There was a significant difference in 10 m sprint speed between indoor (1.80 ±0.13 s) and outdoor (1.91±0.18 s) conditions; this significant variation was present in male, but not female subjects. This approximate 0.1 s variation was also present between combined gender 20-m sprint times indoor (3.31±0.23 s) and outdoor (3.40±0.36 s). Yet in contrast to 10 m, these values were not significantly different, and the effect size was low (0.30). Further, there were no significance differences and low effect size values across all data analysis for "flying" 10 m, and backwards 10-m sprints. The slight differences in sprint performances may have been connected with the terrain and footwear grip (sports hall floor *versus* grass and training shoes with flat soles) rather than climate! Therefore, it would appear that terrain is another factor that should be kept consistent in the set-up of testing within a soccer club. Furthermore, the terrain and footwear should be detailed within the procedures of soccer-field testing, for the purpose of contrasting data between soccer clubs. This contrast between surfaces whose characteristics may change with weather conditions is a practical problem facing those working in a sports science support role in soccer.

Additionally, when comparing the sprint results with data from other test sessions or different teams, it is essential that investigators also report the start procedures of the sprint protocol. The location of foot position at the start of a speed test can make a considerable difference in sprint times (Ekblom, 1992), and it is a factor that is often omitted from many reports of methodologies within research, limiting comparisons of speed data within the literature. In this study, the start position was standardised in the centre at 1 m behind the first electronic photocell that was positioned at the 0 m marker; this was in order to prevent the forward lean typically used at the start of the test from breaking the infrared beam, and consequently causing a false start. Using this protocol, elite U-15 Premier League Academy soccer players have been found to have 10-m sprint times of 1.64 ±0.06 s and for 20-m 3.01 ±0.11 s (unpublished observations for the English Football Association).

There were no significant changes in combined gender, male, and female values between agility left-hand side start times and effect size values were also low. The best mean time of the Doha College students for agility "left-hand side start" was 0.37 s slower when compared to elite Premier League Academy players of a similar age - 4.43 ±0.17 s (unpublished observations for the English Football Association). The agility tests performed from a "right-hand side start" were also not significant across all data analysis. The Doha College students were roughly 0.28 s slower for agility right-hand side start, when contrasted with elite Academy players of a Premier League club (4.52 ±0.17 s) (unpublished observations for the English Football Association). Both students and elite players produced slightly slower times for the agility right-hand side start, which involves 3 cuts to the right and 2 to the left (agility left-hand side start, 3 left cuts, 2 right cuts). This trend possibly highlights a lack of proficiency in changing direction to the right, or a greater ability at cutting to the left with both students and elite young players. Such observations are useful information for the practitioner, as well as justifying the inclusion of tests with dual direction.

8.8 Subject population

The objective of this study was to evaluate the absolute performance differences of soccer field tests that are employed within this thesis, conducted in hot and controlled ambient environments, respectively. Male and female subjects were recruited within this investigation to increase the subject number and hence power of the study (Borenstein et al., 1997).

It is acknowledged that there is a limitation to the findings, a result of the mixed adolescent subject population employed within this study. The suitability of the adolescent subject population was not ideal, and a more applicable subject population would have been drawn from local Qatari professional players had it been feasible to do so.

There is the potential for large differences in absolute performance capacity between youth soccer players (16 years) and adult elite professional soccer players. Several investigators (Beunan *et al.,* 1997; Baquet *et al.,* 2006) have found physical maturation to be an important contributor to increased motor performance, with changes in growth and hormonal levels key factors to performance improvements from 16 to 18 years of age (Anderson, 1994). Additionally, the professional soccer players have had a greater number of training years and as a product of such conditioning are generally physically superior in comparison to college students. Therefore, potential complications may manifest with extrapolating the results of the Doha college students to elite professional soccer players. Hence, the absolute duration of aerobic tests and intensity of anaerobic tests performed by elite professional soccer players is highly likely to be greater than the subjects' capabilities employed in this investigation. The influence of a hot environment on elite professional soccer players performing the battery of field tests employed within this study is to date unclear!

It is further recognized that there are potential problems associated with using mixed gender subjects. Gender differences in performance have been highlighted by Bale and co-workers (1992) who found adolescent boys to be significantly superior to girls in strength, muscular endurance, aerobic capacity, anaerobic power, speed, agility, height, lean and total body mass, and percentage body fat. Conversely, females were observed to have significantly greater flexibility than males.

There were also significant variations noted with regards gender somatotype between the ages of 13 to 18 years, with males possessing more mesomorphic characteristics than females. Conversely, the girls were observed to be more ectomorphic than boys. Furthermore, Bale and colleagues (1992) found a greater body fat percentage and endomorphic characteristics to be significantly related to poorer performance in aerobic capacity and speed tests. Consequently, the athletic capabilities of the mixed gender students would be more far more varied in contrast to a more homogeneous professional soccer population.

8.9 Conclusion

There are many soccer clubs that must conduct soccer-specific performance field tests in outdoor environments. The lack of research within this area means that the influence of environmental stress on discrete aspects of performance tests is unclear. The key finding from this study was the significant reduction in the YYIRT performance when conducted outdoors. There was a 19% decrease in distance covered in the YYIRT conducted outdoors in the heat, despite similar maximal heart rate values to the indoor test, and an explanation for this phenomenon is unclear. There was also a significant difference between the mean values for 10-m times. It was suggested that terrain and footwear may have been influential factors in the changes in sprint performances between the different environments, and should be kept constant between tests. Accordingly, there is some difficulty in transferring results from youth to adult players nevertheless, it was concluded that (with the exception of YYIRT) the test battery is sufficiently robust for administration in a Ramadan context.

Chapter 5

Study 3: A qualitative analysis of lifestyle changes and soccer training during and after the holy month of Ramadan.

9.0 Introduction

The religious festival of Ramadan involves 4 weeks of intermittent fasting in which, no food or water is permitted to pass through the lips of Muslims between dawn and sunset. This study will involve a qualitative analysis of several important factors associated with Ramadan and professional soccer training. During Ramadan Islamic societies reverse their circadian routine of eating and drinking to adhere to the abstinence requirements of their faith. Accordingly, there is a disruption of their nocturnal sleep-wakefulness cycles, which along with body temperature are the main biological rhythms associated with sports performance. The sleep-wake cycle is connected with habitual activity, which is harmonised with the natural occurrence of daylight and darkness (Reilly, 2003).

Chronic sleep disruption can hinder training and performance (Reilly and Piercy, 1994) especially endurance capacity, which has been found to be reduced by 11% (Martin, 1981). Furthermore, a reduction in concentration has also been noted, and there may even be health implications as sleep is associated with the immune system (Reilly, 1995). Zerguini and co-workers (2007) investigated two professional soccer teams during Ramadan in Algiers and found that 70% of players subjectively reported poor quality sleep, impairment in training and performance. Many Islamic soccer federations and coaches alter their training and fixture times to late evening (21:00-22:30 hours) to accommodate these changes; thus, the opportunity to investigate a unique situation is possible. There is a lack of research associated with circadian rhythm variations during and outside Ramadan. Consequently, there is no physiological model to aid an understanding of the disturbances to homeostasis that occur in athletes during the holy month. So far it has been hypothesized that the Ramadan phenomenon is a hybrid of ageing, jet-lag, and shift-work models (Reilly and Waterhouse, 2007). The purpose of this element of the study is to monitor habitual lifestyle changes of professional Qatari soccer players. The particular focus of attention was on changes in the daily sleep-wake cycle during and outside Ramadan.

Probably the most consistent physiological observation amongst fasters throughout Ramadan is transient dehydration. During the early days of the intermittent fast, significant reductions in body weight have been noted (Angel *et al.,* 1975; Husain *et al.,* 1987; Hallak *et al.,* 1988). It has been suggested that this weight loss is a result of dehydration. Water consumption has been seen to decrease, in association with significantly higher serum values of sodium, chloride, and protein when comparing pre-fasting with the end of week-1 of Ramadan analysis (Sweileh *et al.,* 1992).

Other factors that would contribute to a rapid reduction in body fluids include an initiation of caloric restriction. Certain amounts of weight loss will occur from oxidation of carbohydrates and fats for energy provision. As much as 3 grams of water are stored for every gram of carbohydrate. It is not clear, how much water that is associated with glycogen stores is lost from the body as energy stores become depleted (Maughan and Shirreffs, 2004). If dehydration is present, any acclimatization and improved ability to tolerate and cope with heat stress are lost. There seems to be no physiological adaptation to dehydration, and restricted fluid intake can be dangerous (Sawka and Pandolf, 1990). It has been recommended that athletes restrict body mass losses to no more than 1-2% body mass pre–activity (Coyle, 2004). Prior dehydration will impair performance of both short-term high-intensity exercise and prolonged exercise (Maughan and Shirreffs, 2004).

Daily standardised monitoring of body weight before and after training can assist in estimating the hydration status of the soccer player. The pre-training body weight and the amount of sweat lost during the session can be compared with baseline body weight to provide useful information on individual as well as squad rehydration strategies. Each kilogram lost reflects 1 litre of bodily fluids (Hodson, 2000). However, more than one hydration index is necessary as errors can arise when monitoring body mass as the sole index for hydration status. Urine colour, volume, conductivity, as well as specific gravity are other methods of assessing hydration status. More accurate results can be obtained, and useful feedback provided from a relatively quick urine osmolality test.

The objective in this part of the thesis is to examine hydration status of the soccer players before, and after training sessions during and outside Ramadan. Body fluid losses as little as 2% body weight can negatively influence performance; a loss of 5% can result in a 30% reduction in physical work potential (Murray, 1998). The impact of hypohydration on intermittent performance has not been studied much.

The training environment in Qatar can be extreme with frequent temperatures in the mid-30°C range, and at certain times humidity levels are >80%. The simultaneous combination of exercise, dehydration and heat stress inflicts arguably the most severe physiological challenge for an individual other than disease or serious loss of blood (Murray, 1998). So the addition of intermittent fasting and potential chronic dehydration over a month highlights the necessity of further investigation from both a performance and health perspective for Islamic soccer players in training and games. The effects of the combination of thermal stress and dehydration in soccer can be dramatic. High-intensity efforts covered during a game were found to decrease by 40% (400 m) at temperatures of 30°C in comparison with 20°C (Reilly, 2000) and high-intensity performance within a match is an essential factor of success in modern soccer (Mohr *et al.*, 2003). Therefore, another element of evaluation is the core temperature during training. The physiological response to heat stress is related to body core temperature and signs of heat exhaustion can manifest in core temperatures of less than 40°C (Saltin and Costill, 1988; Maughan and Shirreffs, 2004; Reilly and Waterhouse, 2005). Body temperature is regulated around 37°C and is typically measured via tympanic, oesophageal, rectal, or intestinal through temperature sensitive pills.

The management of top-class soccer players' training and fixture schedule requires a fine balance between daily training load, total life stress, and recovery capability from such stressors. Monitoring these factors has become an essential part of many professional coaching regimens, and facilitates a retrospective analysis that furthers understanding of training (Rosen *et al.*, 2001; Smith, 2003) as well as lifestyle interventions on performance. Data gathered surrounding training can provide key information regarding future programming for soccer players.

During planning of soccer training, it is important to be aware of the potentially detrimental effects of training as well as competition loading with regard to the risk of accumulated fatigue. Rest, recovery, regeneration days as well as weeks need to be incorporated within the planned programme (Smith, 2003).

Today, readily available information on professional soccer training loads during the season is limited, and there is a specific dearth on professional soccer players' training loads during and outside of Ramadan. Few if any soccer clubs in Qatar monitor and quantify training load during the season. Coaches typically rely on craft knowledge and intuition. Consequently, such an uncontrolled manner can lead to excessive overload, insufficient regeneration (Fry *et al.,* 1992), and often sub-optimal performance. This loose approach towards training can be addressed by planning, monitoring, and evaluation. The purpose in this part of the thesis is to quantify the periodisation of training weeks, with particular emphasis on training workload during and outside Ramadan. Consequently, a retrospective analysis of the training programme around Ramadan can be made. Empirical evidence from soccer coaches based within Qatar is that physical performance and tolerance of high-intensity training is less during and following the 4-week intermittent fast. A reversibility of physical adaptations of training can manifest from insufficient training stimuli (Mujka, and Padilla, 2000).

The purpose of these collective observations of habitual lifestyle changes (bedtime, wake-up time, sleep duration), environment, dehydration (pre-training, body fluid loss during training), core temperature, and relative training work-load is to facilitate a greater understanding of soccer practice and stress surrounding Ramadan. A further aim of this study is to use this combined training and lifestyle data to provide relevant background information for potential performance changes that may transpire surrounding Ramadan, to be investigated in Study- 4 *the influence of Ramadan on soccer-specific performance tests.*

9.1 Methods

9.1.1 Research design

The nature of this investigation means that a quasi-experimental design is applicable. The empirical data collected from this research are intended to be of direct value for practitioners. The natural soccer environment provides high ecologically validity. The design has only one group of subjects. The effects of the 4-week intermittent fast period (intervention) will be compared with the 4-week non-fast phase following Ramadan (control period).

9.1.2 Subjects

In this study 20 male professional Qatari soccer players were involved from the 1st team of Al-Ahli, soccer club. Altogether, 14 players were eligible for the complete 8-week analysis. The characteristics of the subjects were as follows and taken on the 4th September 2006 (12 days before the start of the season); age 25 ±3.4 years, height 1.75 ±0.07 m, body mass 71 ± 6.2 kg, body fat % 9.9 ±3.1 (4-skinfold sites, Durnin and Womers, 1974), estimated $\dot{V}O_{2max}$ 52.3 ± 5.6 $ml.kg^{-1}.min^{-1}$ (Ramsbottom *et al.*, 1988) and maximum heart rate 192 ± 6 $beats.min^{-1}$ (Polar Team System, Finland).

9.1.3 Procedures

Unless specified, the following aspects of training were monitored every training day during and post-Ramadan (total 8 weeks). The Ramadan festival was from the 24th September to 23rd October 2006 and the weeks immediately post-Ramadan acted as the control period in this investigation and took place on the 24th of October to the 17th of November 2006. There were 19 and 20 training sessions during the concurrent 56-day analysis of Ramadan and post--Ramadan, respectively. The control condition was structured post-Ramadan in order to evaluate balanced training periods, with regards training demands within season. The weeks preceding Ramadan were part of the pre-season phase and as such training intensities, volume, and numbers of sessions were disproportionate in comparison to in-season training.

The choice of a control period pre-season was considered unacceptable in view of the disturbances to training load and fitness status imposed on the players at this time.

In all training sessions environmental conditions were quantified using a self-calibrating psychrometer (Mannix SAM99ODW, Mannix Instruments, New York) with temperature and relative humidity having an accuracy ±1°C and ±4%, respectively. Wet bulb Globe temperature (WBGT) was used as an index of environmental stress as it was calculated from measures of ambient temperature, relative humidity and radiant heat (McArdle *et al.*, 1996). To investigate circadian variation of the sleep-wake cycle, 10 players volunteered to wear an Actimeter watch (Cambridge Neurotechnology, Cambridge) on the wrist during sleep. Subjects were required to press a marker button manually upon retiring to bed, and upon waking-up in the morning. As a back up, they were also asked the time that they went to bed and woke-up, by the author each day prior to training (see Appendix 2). Bedtimes, wake-up times, and sleep durations are all expressed in minutes, midnight 00:00 hour represents the start of each day, and 1439 min (23:59 hours) the end of the day.

The Qatari League competition typically consists of only one match per week. The day prior to the game, urine osmolality was measured before training to establish dehydration status pre-training. The Osmocheck (Vitech Scientific, West Sussex) was used to provide an indicative reading of urine osmolality. The Osmocheck is a hand-held digital refractometer calibrated from 0-1500 mOsmol/kg H_2O that equates to a specific gravity of 1.000 to 1.043. It has been found to have a high association ($r = 0.989$) when cross-validated against gold standard measurements (Advanced Micro Osmometer, Vitech Scientific, West Sussex) of monitoring dehydration via urine. The results from the Osmocheck are instantly displayed within ±10 mOsmol/kg H_2O. Before the measurement took place, the pocket Osmocheck was calibrated with Renol urine osmolality control (Advanced Instruments, Massachussetts, USA) with the low value of 300 msOsm/kg H_20. All players were weighed before (Seca 761 mechanical floor scales, Hamburg, Germany) and after training in their dry underwear. During training each player's water bottle (1-20 marked with squad numbers) was filled to 1000 ml.

When or if the bottles became empty from consumption, they were refilled back to 1000 ml to facilitate approximating water consumed during training. There were no directives on water consumption; ingestion was ad libitum to observe current practice.

Two central midfield players volunteered to participate in core temperature evaluation during training once a week (total 8 weeks) during the most intense training session, as determined by the head coach. The CoreTemp™ disposable temperature sensor pill (Palmetto, FL) was individually calibrated in the factory, and the calibration adjustment number was entered in the miniaturized ambulatory receiver (CoreTemp™ 2000) (Palmetto, FL) prior to use, to ensure a temperature accuracy of ±0.1 degree Celsius. The sensor pills were given to the players the day before assessment, to take at least 2 hours before training and ingested with tepid water, as per directions of manufacture following the breaking of the fast.

Prior to this study maximum heart rate was measured during a shuttle run to estimate $\dot{V}O_{2\max}$ (Multistage Fitness Test, Ramsbottom *et al.*,1988), using data output from the Polar Team System (Finland). Subsequently, players' relative heart rate zones were specified and workload was calculated using a modified *TRIMP* (training impulse) method (*training minutes x heart rate zone intensity*) (Brandon, 2005). Consequently, time spent in the various relative intensities inside and outside Ramadan was evaluated.

9.2 Statistical Analysis

Descriptive statistics were used to highlight the mean value and spread of data between the subjects. To investigate the main effects of Ramadan and the separate weeks during Ramadan, a 2 and 4-level repeated measures ANOVA was employed. If significance was present within the 4-level repeated measures ANOVA, pair-wise comparisons were used. Epsilon was used to correct the degrees of freedom based on guidelines of Girden (1992); significance was set at $P \leq 0.05$.

Where appropriate, to illustrate the magnitude (meaningfulness) of differences between experimental and control weeks, effect size calculations were utilized (Ramadan (intermittent fast) – non-Ramadan (control-non fasting)/pooled standard deviations) (Hopkins *et al.,* 1999).

9.3 Results

9.3.1 TRIMP values results

There was no significant difference ($F_{1,2} = 8.26$; $P = 0.103$) in relative training intensity during or after Ramadan, or between the weeks within Ramadan ($F_{1,2.01} = 2.60$; $P = 0.248$) (Figure 16). The mean TRIMP values for Ramadan were 179 ± 61 and for non-Ramadan 116 ± 46; consequently, the effect size of 1.17 suggests a large reduction. There was no significant interaction between the weeks of training intensity during and after Ramadan ($F_{1.19,2.38} = 1.64$; $P > 0.05$).

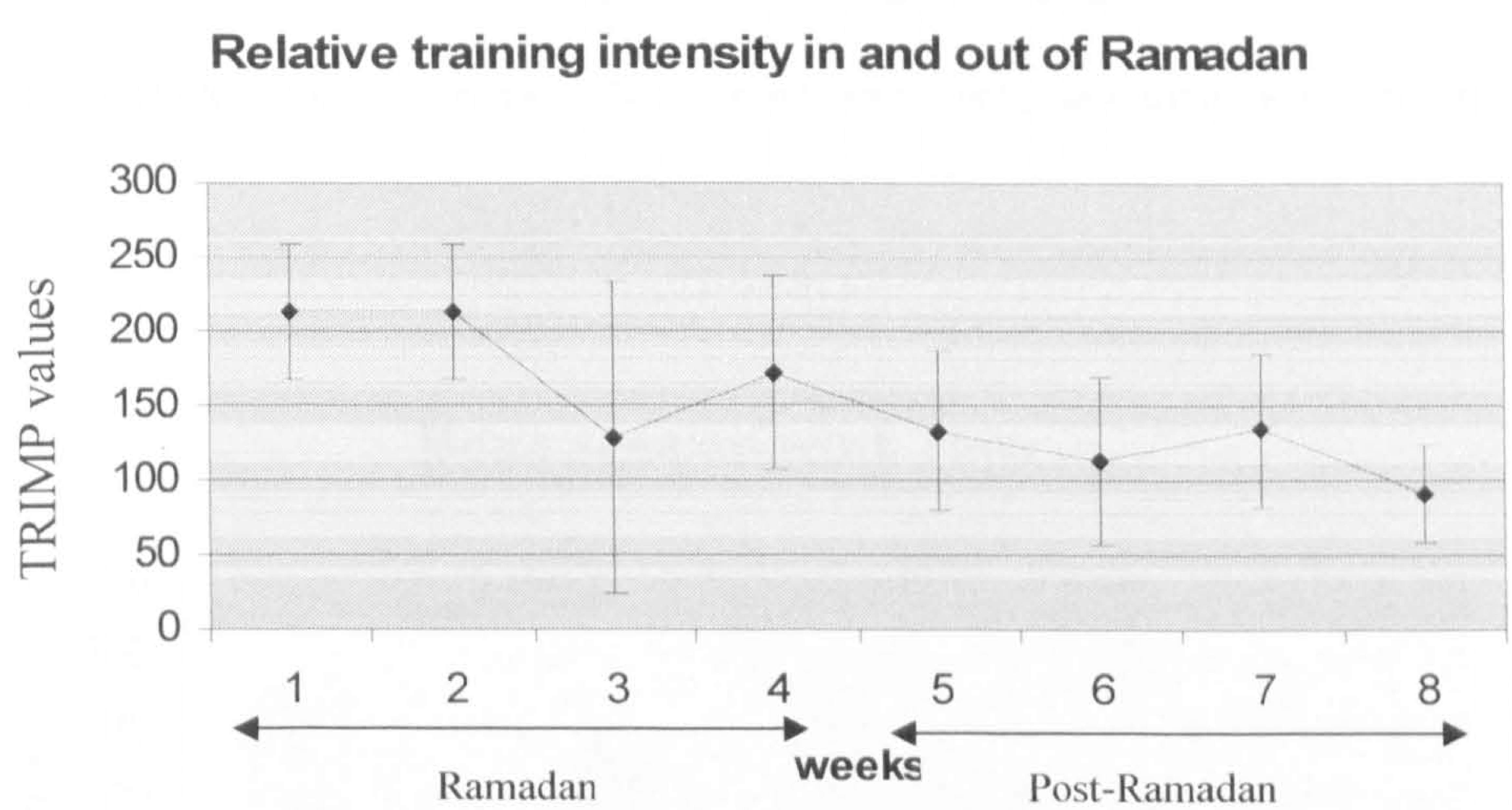


Figure 16. Mean and SD for TRIMP values during weeks 1-8 before and after Ramadan (n= 14).

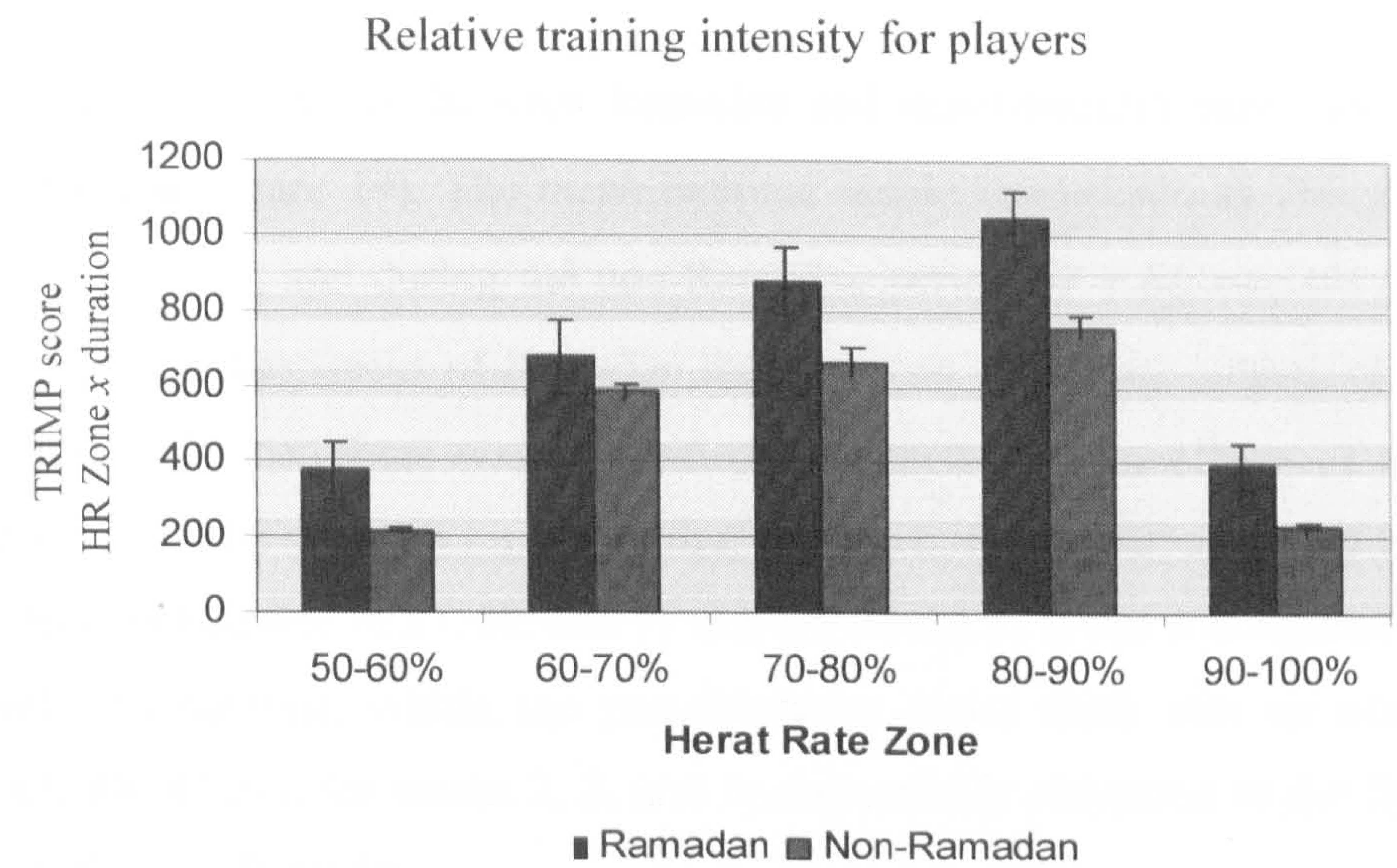


Figure 17. TRIMP Mean values for respective heart rate intensity zones during Ramadan and non-Ramadan (n=14).

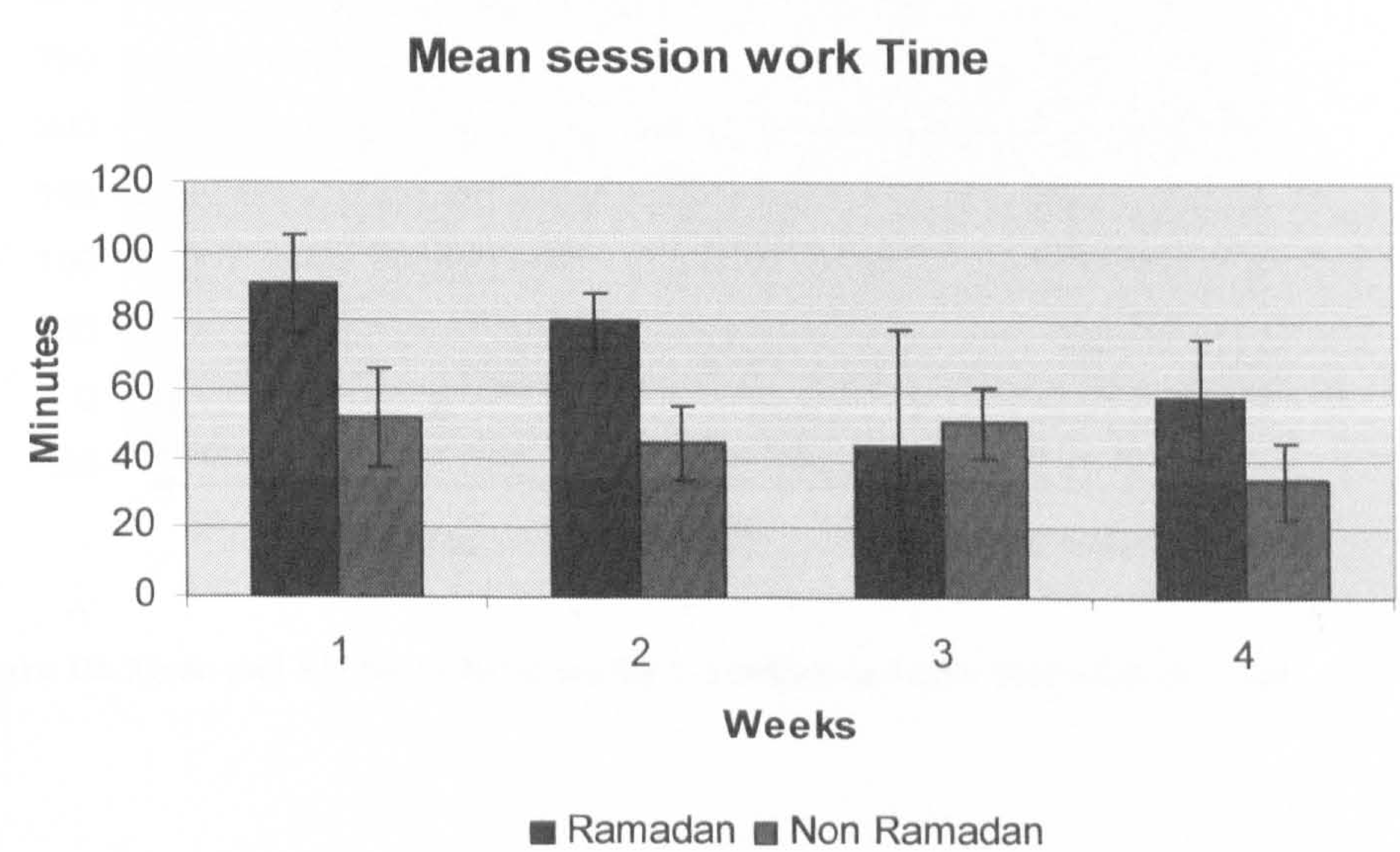


Figure 18. Mean session daily work time during Ramadan and non-Ramadan (n=14).

9.3.2 Bedtime results

There was a significant change between Ramadan and non-Ramadan bedtimes ($F_{1,9}$ = 168.71; $P < 0.001$) (Figure 19). The mean bedtime inside Ramadan was 266 ± 32 min (04:43 hours ± 32 min), and during the non-Ramadan period 67 ± 61 min (01:07 hours ±01:01 hours). Within the weeks of Ramadan there was no significant change of bedtime ($F_{3,27}$ = 1.905 $P > 0.05$). There was a significant interaction of the effects of Ramadan between the weeks of the study ($F_{3,27}$ = 11.24; $P < 0.001$) . During the weeks of Ramadan there was a delay in bedtime of 27, 52, and 77 min for weeks 2, 3, and 4 compared to week 1, respectively. In contrast, within the post-Ramadan phase there was an advance in bedtime of 83, 80, 80 min for weeks 2, 3, and 4, respectively compared to the first week immediately following Ramadan.

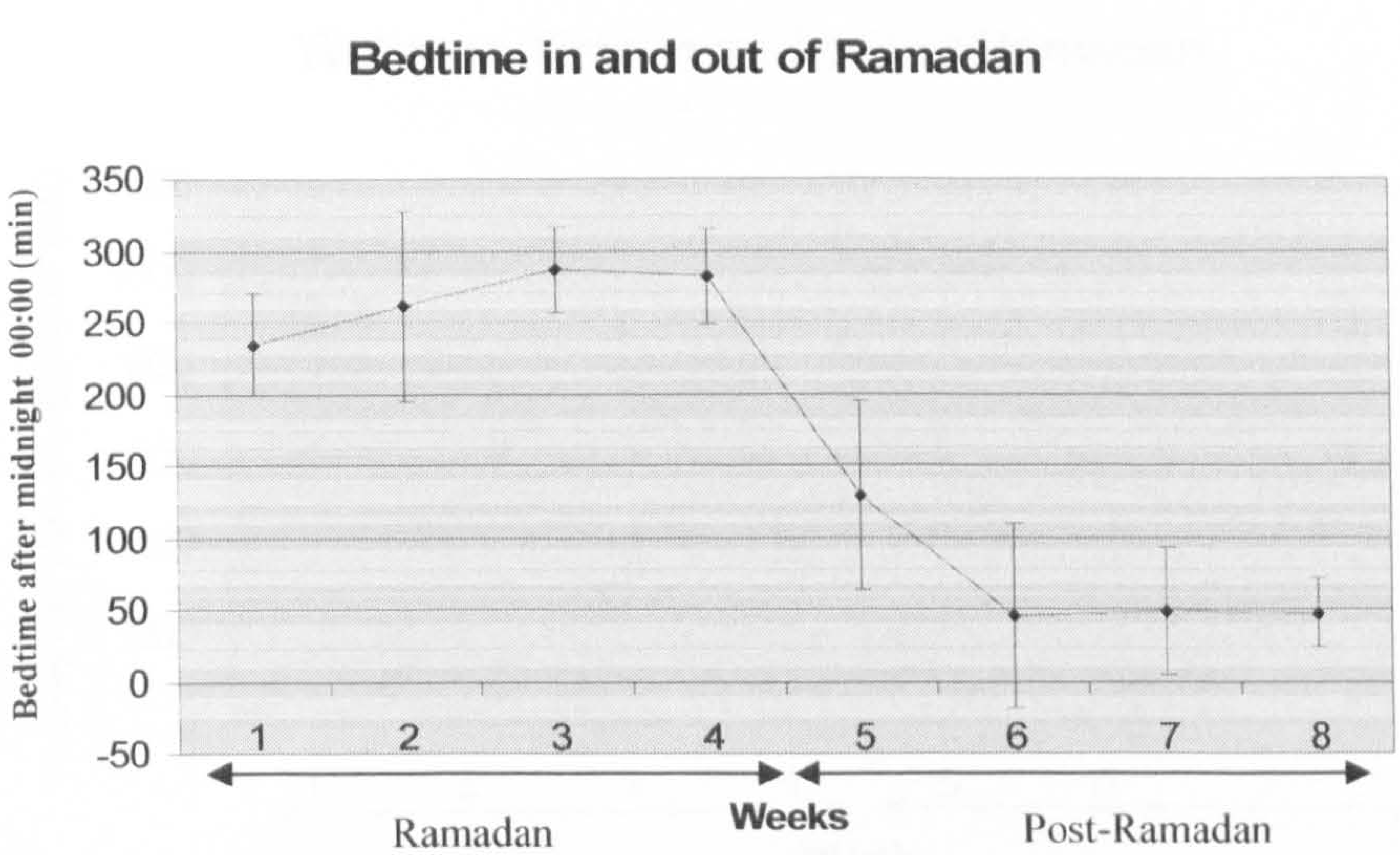


Figure 19. Mean and SD for bedtime weeks 1-8 before and after Ramadan (n = 14).

9.3.3 Wake-up results

A significant change ($F_{1, 9} = 162.57$; $P < 0.001$) in wake-up times between Ramadan and non-Ramadan weeks was also evident (Figure 20.). During Ramadan the mean wake-up time was 855 ±98 min (14:25 hours ±01:38 hours), in contrast to the non-Ramadan phase which was 557 ± 62 min (09:17 hours ±01:02 hours). Within the weeks of Ramadan, wake-up time was not significantly different ($F_{1.68, 15.1} = 2.43$; $P > 0.05$). A significant interaction was observed between the weeks of this investigation ($F_{2.23, 27} = 11.80$; $P < 0.001$) . During the weeks of Ramadan wake-up time was further delayed from week-1 by 27, 52, and 77 min for weeks 2, 3, and 4, respectively. In contrast, within the non-Ramadan period there was an advance in wake-up time from week-1 of 83, 65, 69 min for weeks 2, 3, and 4, respectively.

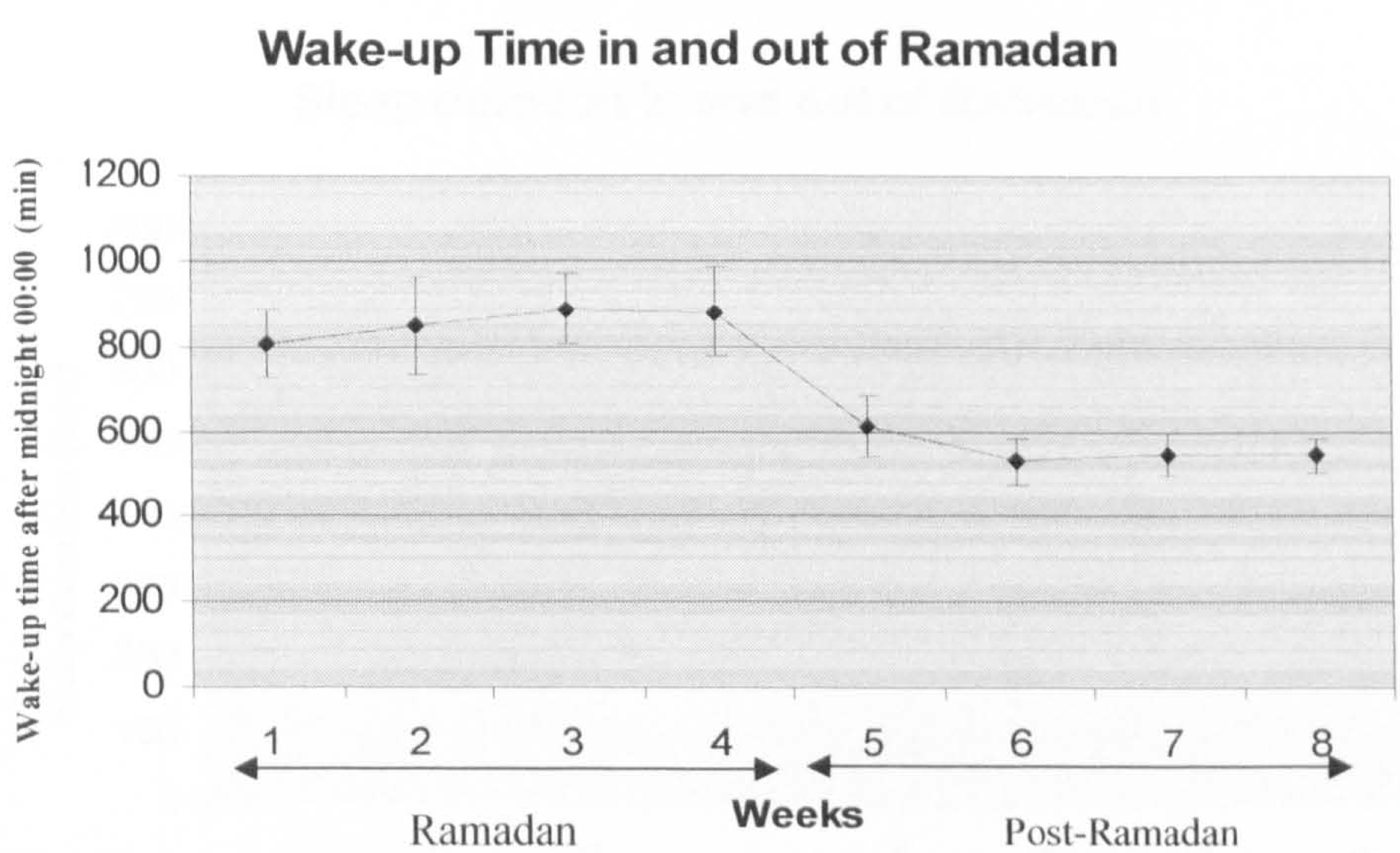


Figure 20. Mean and SD for wake-up weeks 1-8 before and after Ramadan (n = 14).

9.3.4 Sleep duration results

The duration of sleep within Ramadan was significantly greater than non-Ramadan ($F_{1,9}$ = 25.0; $P < 0.05$) (Figure 21). The mean duration of sleep during Ramadan was 589 ± 85 min (09:49 hours ±01:25 hours), and in the non-Ramadan period 490± 42 min (08:10 hours ±00:42 hours). The separate weeks during Ramadan were not significantly different ($F_{3,27}$ = 1.40; $P > 0.05$) from each other regarding duration of sleep. No significant interaction was evident ($F_{2.06, 18.54}$ = 0.235 $P > 0.05$) for sleep duration for the weeks during and following Ramadan .

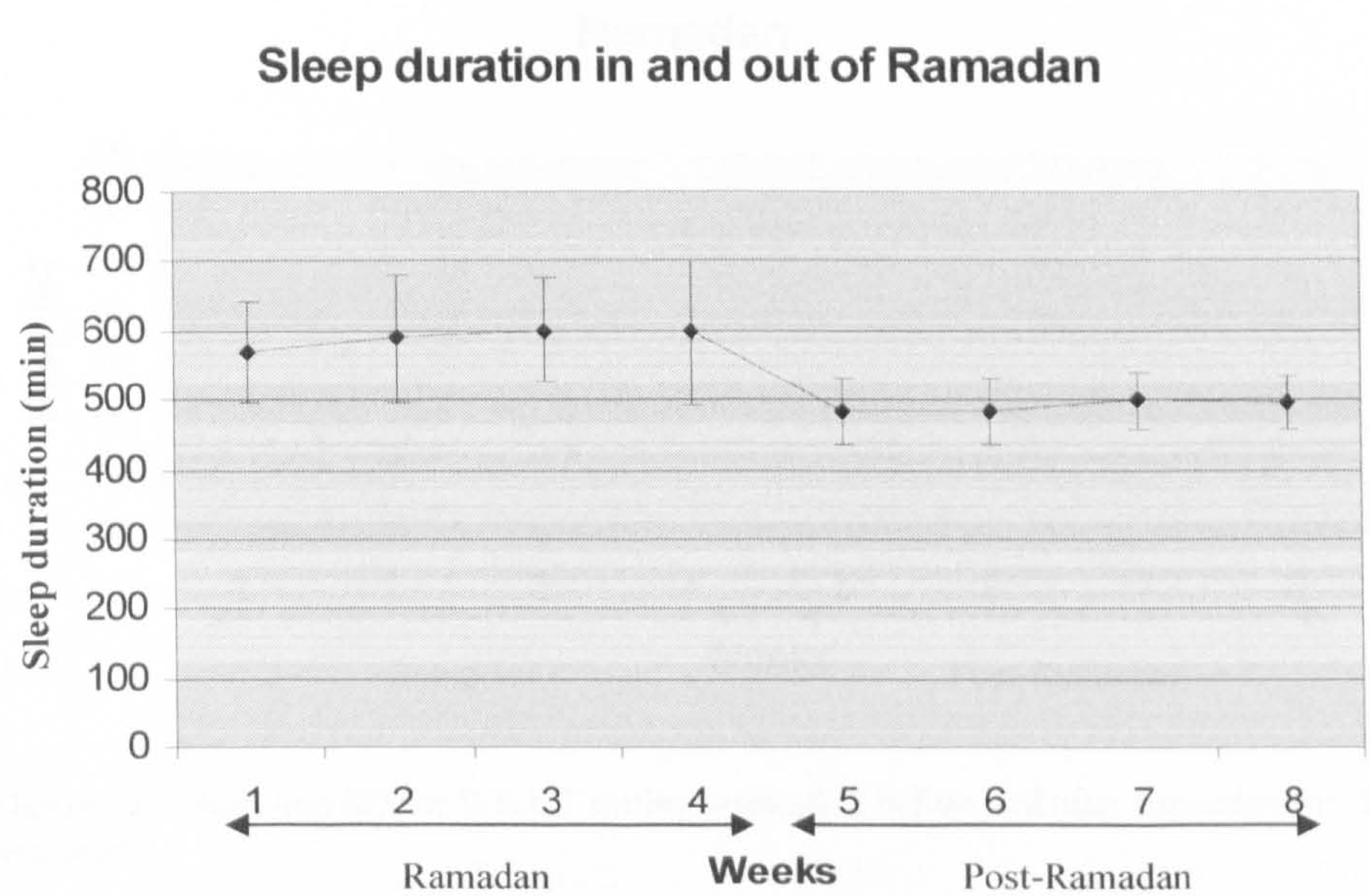


Figure 21. Mean and SD for sleep duration weeks 1-8 before and after Ramadan (n=14).

9.3.5 Environmental conditions

There was no significant difference ($F_{3, 27} = 1.40$; $P > 0.05$) in environmental climate between Ramadan and non-Ramadan weeks, a WBGT of 1.8 °C separating the respective means (Figure 22). Within the weeks of Ramadan no significant changes were observed ($F_{1, 1} = 2.28$; $P > 0.05$). The mean environmental surroundings during Ramadan was WBGT 25.7 ± 2°C, and for the non-Ramadan block of weeks WBGT 23.9 ± 2°C. The four weeks periods during and post-Ramadan also yielded no significant interaction ($F_{1, 1} = 0.656$; $P > 0.05$) for WB GT .

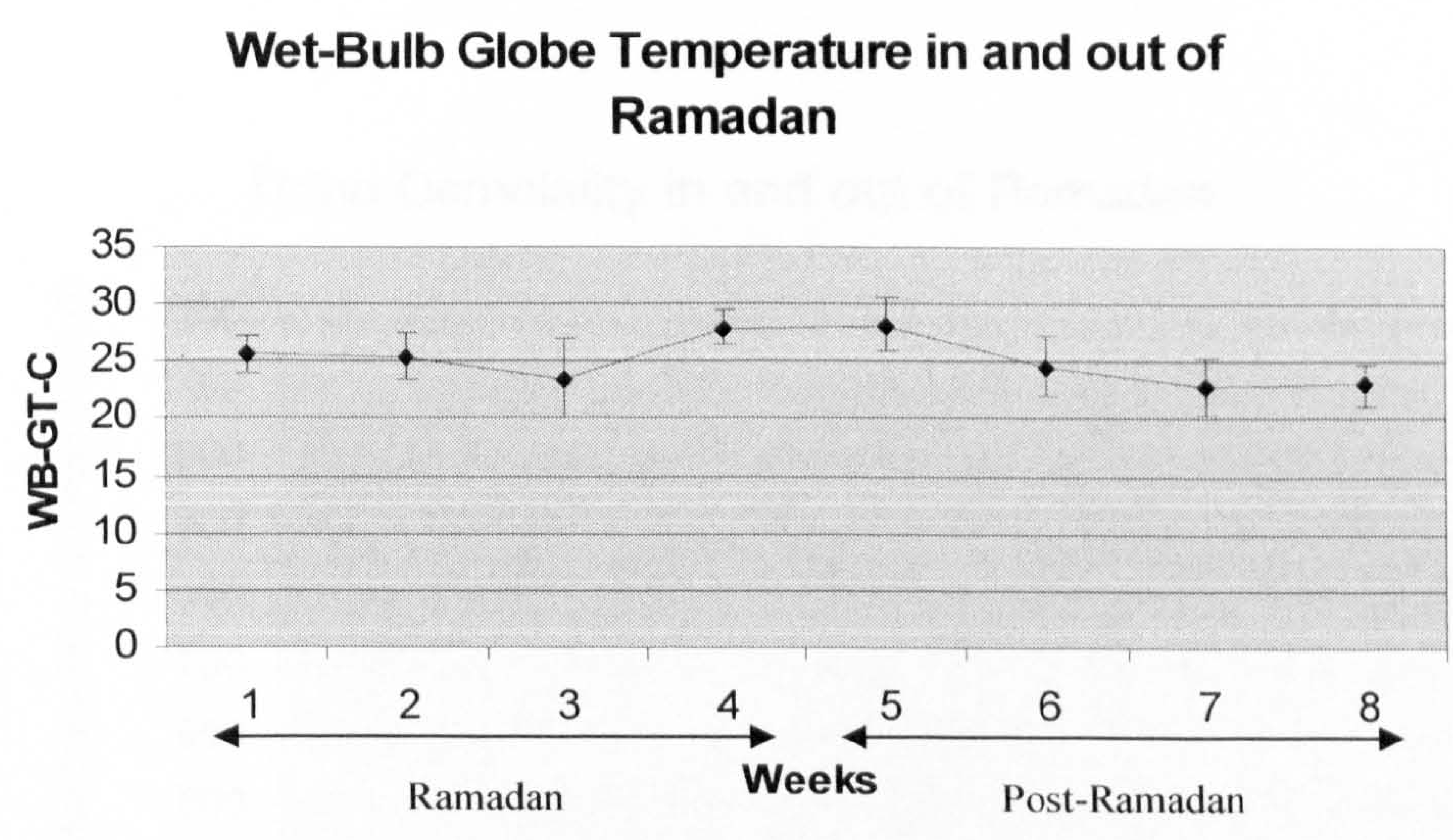


Figure 22. Mean and SD for WB GT during weeks -8 before and after Ramadan (n= 39 training sessions).

9.3.6 Osmolality results

Urine osmolality taken pre-training was significantly different during Ramadan in comparison with non-Ramadan ($F_{1, 11} = 17.54$; $P < 0.05$) (Figure 23). The mean urine measurement within Ramadan was 825 ± 143 mOsmol/kg H_2O compared with 708 ± 155 mOsmol/kg H_2O in the non-Ramadan observation. There was also a significant difference during the weeks of Ramadan ($F_{3, 27} = 3.42$; $P < 0.05$); pairwise comparisons found a significant difference (P = 0.038) between week 1 and week 4, a reduction of 159 mOsmol/kg H_2O. No significant interaction ($F_{1.98, 21.78} = 1.17$; $P > 0.05$) was evident for urine osmolality in and out of the weeks of Ramadan and non-Ramadan, respectively .

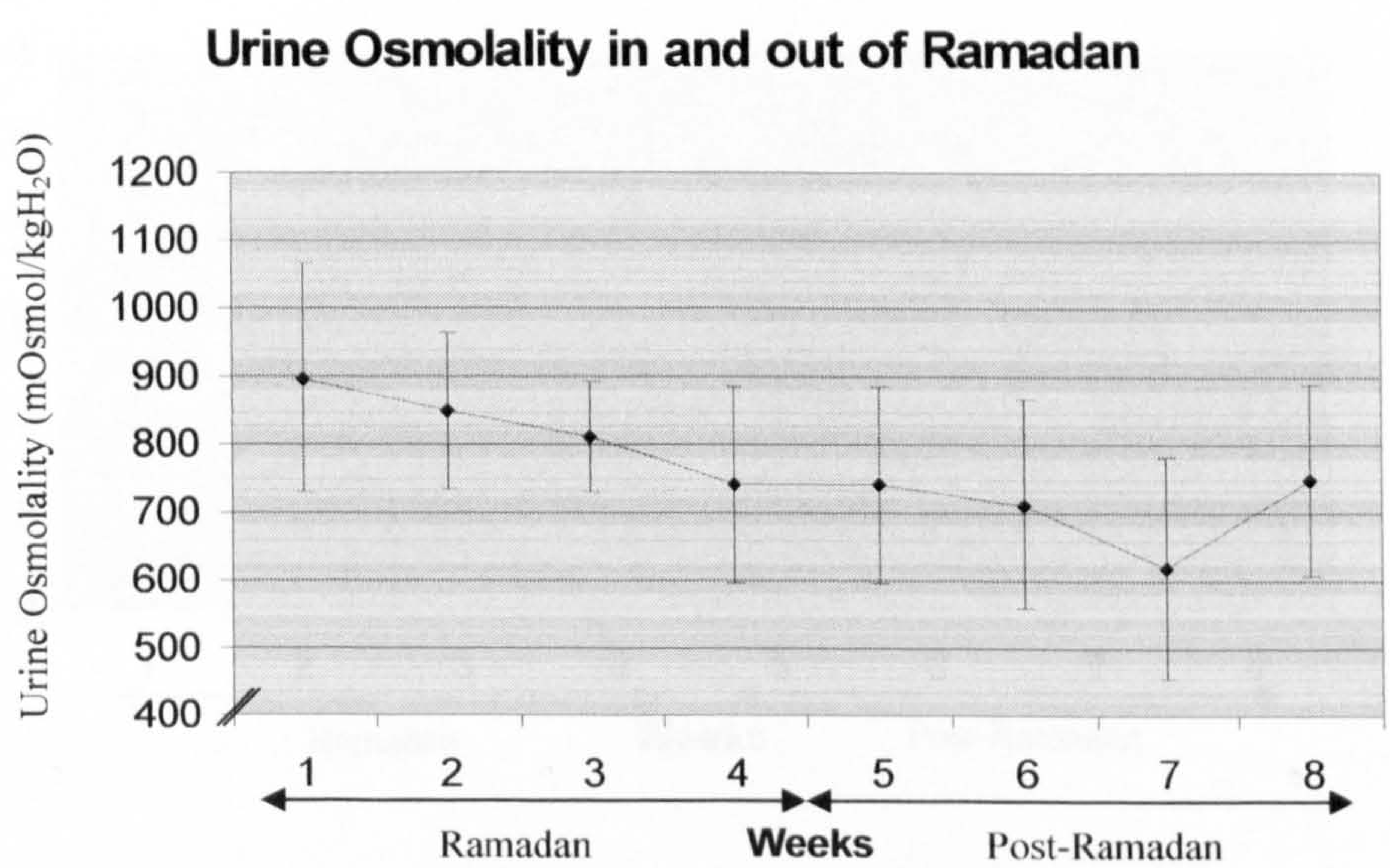


Figure 23. Mean and SD for urine osmolality during weeks 1-8 before and after Ramadan.

9.3.7 Body fluid loss results

The amount of body fluid lost during training was not significantly different between Ramadan and non-Ramadan ($F_{1, 2} = 4.68$; $P > 0.163$) (Figure 24). There were also no significant changes within the weeks of Ramadan ($F_{1.17, 2.33} = 1.53$ $P > 0.05$). The mean body fluid loss during training in Ramadan was 1.9 ± 0.6 l, in contrast to 1.5 ± 0.5 l for the non-Ramadan weeks, with a moderate effect size of 0.68. There was no significant interaction ($F_{1.57, 3.13} = 1.16$; $P > 0.05$) in body fluid loss between the weeks of Ramadan.

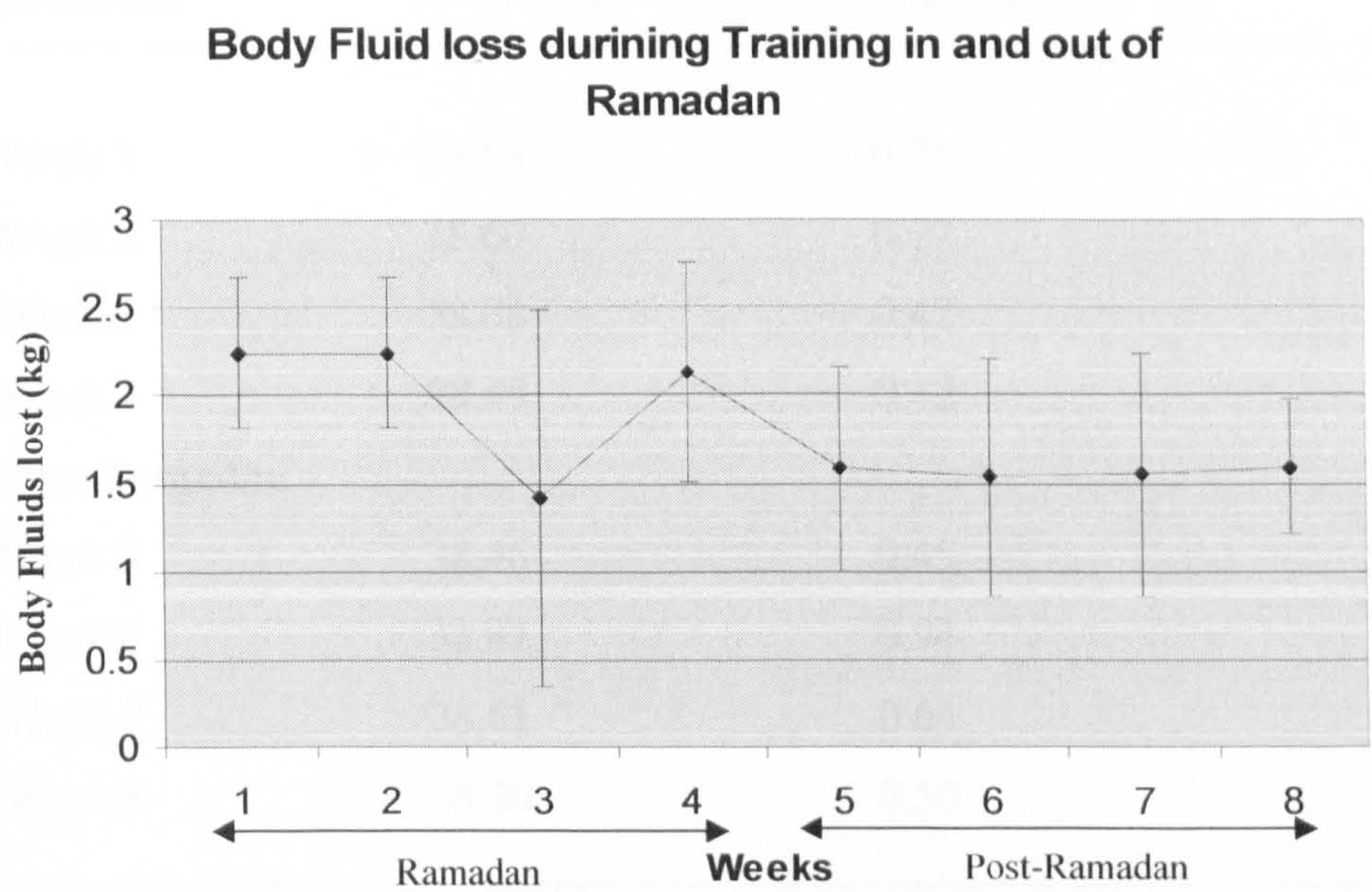


Figure 24. Mean and SD for body fluid loss during weeks 1-8 before and after Ramadan (n=14).

9.3.8 Core temperature results

Throughout Ramadan soccer training started between the hours of 20:31 to 21:30 hours, and in non-Ramadan training began earlier at 17:30 or 18:00 hours. During the four weeks of and the immediate four weeks post-Ramadan, the mean core temperature of two centre midfield players was 38.4 ± 0.6 °C and 38.5 ± 0.7 °C, respectively. Table XXIII shows the mean, and standard deviation for the respective weeks surrounding the Ramadan festival, and Figure 25 displays the peak body core temperatures of the two players recorded during training within the same period.

Table XXIII: Mean and standard deviation core temperature of two center midfield players during training surrounding Ramadan.

Ramadan	Mean (Tcore °C)	Std Dev (Tcore °C)
Week 1	38.56	0.77
Week 2	38.60	0.77
Week 3	38.08	0.42
Week 4	38.48	0.42
Post-Ramadan		
Week 5	38.46	0.45
Week 6	38.87	0.94
Week 7	38.61	0.64
Week 8	38.20	0.50

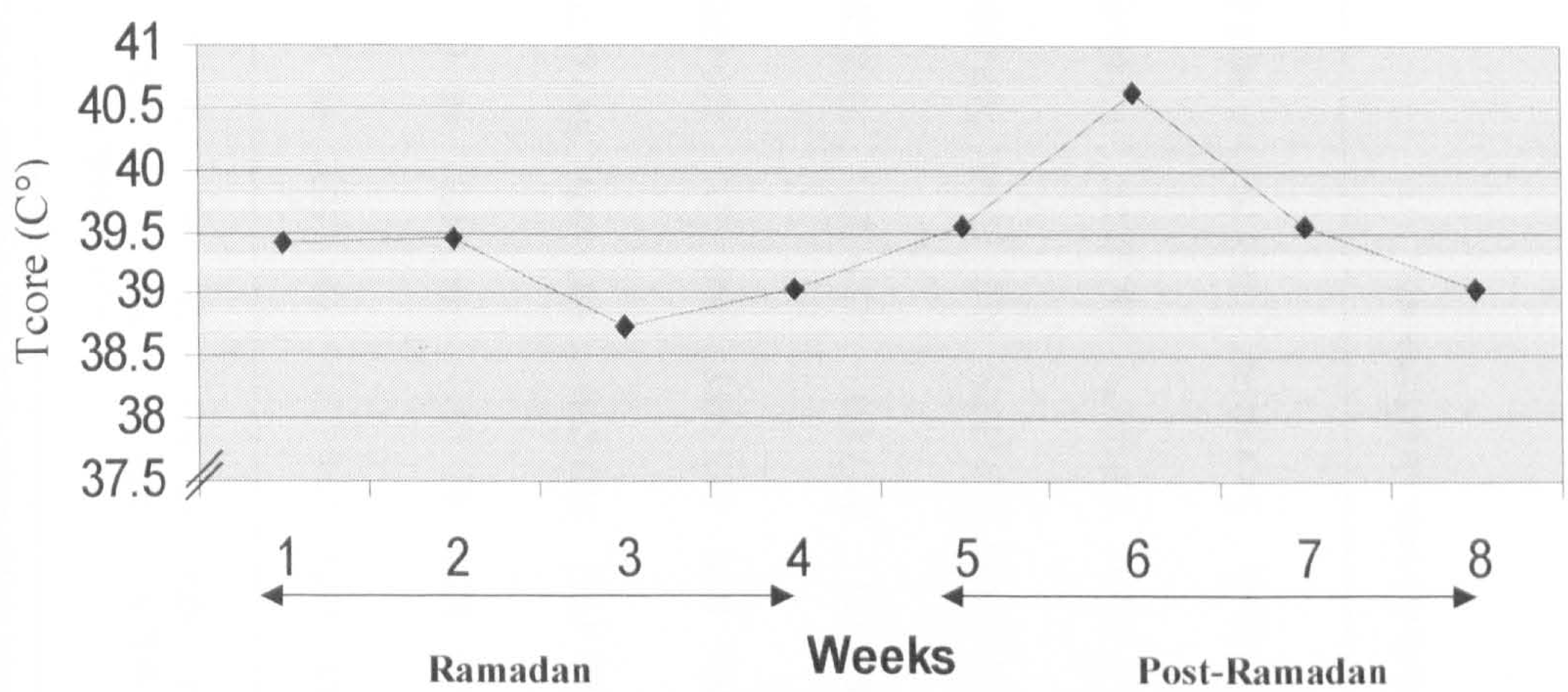


Figure 25. Peak core temperatures during training of two centre midfield players in the weeks surrounding Ramadan (n=2).

9.3.9 Results summary.

Table XXIV: Mean and standard deviation of relative training intensity, circadian sleep-wake cycle and hydration status.

	Ramadan					non-Rmadan				
	WK1	WK2	WK3	WK 4	TOTAL	WK 5	WK 6	WK 7	WK 8	TOTAL
	M SD	M SD	M SD	M SD	M SD	M SD	M SD	M SD	M SD	M SD
1. TRIMP (Training minutes x heart rate Intensity zone)	214 (46)	182 (35)	128 (103)	172 (66)	179 (61)	133 (53)	114 (51)	134 (50)	91 (29)	116 (46)
2.Bedtime (min)	234 (35)	261 (66)	286 (30)	281 (32)	266 (47)	128 (65)	45 (64)	48 (45)	48 (25)	67 (61)
3. Wake-up (min)	804 (77)	850 (115)	887 (84)	879 (103)	855 (98)	612 (73)	529 (54)	547 (49)	543 (37)	557 (62)
4. Sleep D (min)	570 (73)	589 (93)	601 (76)	598 (105)	589 (85)	484 (47)	483 (45)	499 (41)	495 (37)	490 (42)
5. WBGT (°C)	25.5 (2)	25.1 (2)	23.5 (3)	28 0 (1)	25.7 (2)	28.2 (2)	24.7 (3)	23.9 (2)	23.9 (2)	24.5 (3)
6. Osmol (mOsmol/kg H_2O)	898 (170)	848 (114)	809 (81)	742 (145)	825 (143)	742 (145)	713 (153)	618 (164)	747 (141)	708 (155)
7. Fluid loss (l)	2.2 (0.4)	1.8 (0.4)	1.4 (1.0)	2.1 (0.6)	1.9 (0.6)	1.6 (0.6)	1.5 (0.7)	1.6 (0.7)	1.5 (0.4)	1.5 (0.5)
8. Tcore (°C)	38.6 (0.8)	38.6 (.8)	38.1(0.4)	38.4 (0.4)	38.4 (0.6)	38.4 (0.4)	38.9 (0.9)	38.6 (0.6)	38.2 (0.5)	38.5 (0.7)

Note:
For 1 (Bedtime) and 2 (Wake-up) data are expressed in min. Start of each day 00:00 hour / End of each day 1439 min (23:59 hours)

M = mean
SD = Standard Deviation
TRIMP = Training Impulse
Sleep D = Sleep Duration
WBGT = Wet Bulb Globe Temperature
Osmol = Osmolality
Tcore= Core Temperature

9.4 Discussion

There was no significant difference between Ramadan and non-Ramadan phases in relative training intensities as measured by TRIMP values, but a large effect size difference between the means was evident. The effect size suggests a greater relative training intensity for the players during Ramadan in contrast to the non-Ramadan period (Figure 14). A closer examination of time spent in training zones (80-90 and 90-100% HR_{max}) during Ramadan highlights a 27 and 41% reduction in high-intensity work in contrast to non-Ramadan (Figure 16), respectively. Also, there were approximately 44% more training minutes in the first two weeks of Ramadan in comparison to the first 2 weeks of non-Ramadan, despite the number of training sessions being equal for both periods (n = 5); highlighting the volume of work and intensity was relatively greater during the first two weeks of Ramadan in comparison to the latter two weeks of the holy month as well as the four week period immediately post-Ramadan.

It should also be noted that the players experienced problems regarding the coaches' training programme. No consideration or modification of training was made for the Ramadan period, the coach employed a rigid training programme that he had used previously with other teams in a "*cookbook approach*". In breaking down the TRIMP scores, the average session length during weeks 1 and 2 of Ramadan were 91 and 80 minutes per day, respectively (Figure 17) as per normal non-Ramadan training schedule. However, during the early phase of Ramadan the potential debilitative effects of Ramadan were at their most severe. Players were trying to adjust to circadian rhythm alterations, balance fluid, maintain a positive calorie intake, cope with extreme environmental stress and substantial body fluid losses during training. Consequently, by the end of week-2 players were complaining of being tired, a lack of energy, poor motivation. Additionally, the coaches reported a poor quality of training and results during games were not good. Therefore, following intervention from the Arabic management of the club, the coach then modified the training sessions and reduced the training volume.

There was no significant difference between TRIMP values during the subsequent weeks of Ramadan. Furthermore, no significant interaction between Ramadan and non-Ramadan occurred; week-3 was an international week for both periods, and the reduced relative intensity during week-3 was roughly the same for both these international weeks explaining the slight skewness in Figure 15.

The use of Actimeter devices supplemented by daily sleep diaries generated novel data on sleep-wakefulness of soccer players during the holy month. This original information was despite some methodological problems associated with data collection via Actimeter monitors. Players would remove the sleep watches for prayer (5 times daily) and also during shower following training. Players sometimes forgot to replace the watch and all ten players did not adhere totally to wearing the watch everyday for the full 8 weeks! Consequently, data analysis was restricted to bedtime, wake-up, and sleep duration collected manually by daily and weekly sleep diaries. Therefore, more in-depth analysis such as sleep latency as well as sleep efficiency was not possible.

There was a significant difference between Ramadan and non-Ramadan bedtime, with a delay of 198 min (3 hours 18 min). Yet, there was no significant difference between bedtimes during the separate weeks of Ramadan. Previous research regarding circadian variation and athletes during Ramadan is lacking (Reilly and Waterhouse, 2007). Nevertheless, the results support previous limited findings of a delay in bedtime in sedentary subjects (Roky *et al.,* 2004; Bahammam, 2005), who also noted phase shifts in rhythms of body temperature with reduced amplitudes as well as a delay in acrophase by 2-3 hours.

There was a significant interaction of bedtime and a combination of factors is likely to have led to the pronounced postponement of bedtime with Qatari soccer players during Ramadan in comparison to non-Ramadan period. Firstly, following the late night training it is likely that catecholamine levels would be elevated (Reilly, 2003). Noradrenaline is a hormone closely related to adrenaline that belongs to the catecholamine group of substances and inhibits melatonin secretion. Melatonin promotes sleep and influences the setting of the body's biological clock (Tortora and Gabowski, 1996).

Players will often struggle to get to sleep at their usual time following an evening game (Reilly, 2003); therefore it is possible that this may also be the case following late night training. It was subjectively reported by many players that even if they went to bed at their normal time, sleep was delayed and so early bedtime was futile. Also, as the first prayer time of the day during Ramadan was at 04:05 to 04:20, and the final meal (suhur) before daybreak is taken just before dawn (Roky *et al.*, 2001), many players delayed bedtime until after eating this meal.

Given the delay in bedtime during Ramadan, it was natural to find that wake-up time was significantly postponed from around 09:00 hours to 14:00 hours. There was no significant difference in wake-up times during the weeks of Ramadan, but there was a significant interaction. Wake-up time was deferred by approximately 75 min from week 1 to 4 of Ramadan, possibly a reflection of the delayed acrophase and shift in circadian rhythms. After Ramadan, there was a pronounced advance of wake-up time during week-5 of the investigation (Figure 16) 268 min (4 hours 28 min). Yet, it was not until around two weeks following Ramadan that wake-up time stabilized and returned back to normal, an advancement of roughly 5 hours compared with the Ramadan period.

Sleep duration was also significantly increased by around 90 minutes between Ramadan and non-Ramadan. During Ramadan, sleep duration was lengthened by roughly 40 minutes from week 1 to week 4 to a peak of 601 minutes (10 hours and 1 min). The first week following Ramadan, sleep duration had been reduced to approximately 483 minutes (8 hours and 3 min). Generally, individuals aged 20-30 years require around 7 hours sleep per night, and athletes require 8-9 hours sleep (Reilly, 2003). This significant increase in sleep duration during Ramadan may be associated with extended bedtime through poor sleep efficiency during daylight hours, or possibly latency from socializing in the early hours of the night. These observations regarding sleep patterns are highly sensitive, as it is the ethos of Ramadan that all fasters endure the sensations of thirst and hunger throughout the day, so as to have empathy with the poor who have limited food and water. The players generally woke up around 14:00 hours, and the breaking of fast was around 17:10 hours.

The results show that the players actually only experience approximately 3 hours of abstinence of eating and drinking, despite having gone without food and drink since before sunrise. However, it is important to understand that the Islamic player is placed in a difficult predicament (sleep disturbances, homeostatic imbalance following late night training, restricted hours for nutritional recovery, religious adherence to Morning-Prayer, and 8-9 hour general sleep requirements of athletes), and the afternoon wake-up time is understandable given the circumstances.

The sleep-wake cycle of Qatari players may also differ with Muslim soccer players in other countries. Zerguini and collegues (2007) tested players at 14:00 hours normal match time in Algiers, which indicates that they maintained a normal training match-play routine in contrast to the Qatari approach of changing training to late evening (21:00 hours). The Ramadan circadian phenomenon has been suggested to be a hybrid of circadian models aging, jet-lag and shift work (Reilly and Waterhouse, 2007). The evidence from this investigation would support these postulates. The bedtime and wake-up time data are akin to nocturnal shift workers.

The post-Ramadan circadian readjustments may induce symptoms similar to jet lag (digestive discomfort, reduced daytime alertness, lack of energy, disorientation, sleeping difficulties, general grogginess as well as loss of appetite); it was not until two weeks after Ramadan that wake-up time stabilized to a normal level. This period immediately following Ramadan is comparable to eastward travel and advancement of the body clock, as players wake-up earlier in contrast to Ramadan. It has been found that travelling eastward across time zones is more severe and readjustment may take over a week for symptoms to disappear. Arousal adapts more quickly to a new time zone in comparison to core temperature, which is relatively slow at adjusting. When traveling across time zones it takes roughly 1 day per time zone crossed for adaptation to take place (Shephard, 1999; Reilly and Waterhouse, 2007).

There was no significant change in environmental conditions between Ramadan and non-Ramadan. It is recommended that soccer practice be modified considerably and closely monitored for heat stress at WBGT of 23-28°C and greater than 28 °C practice or games are cancelled (Shephard, 1999). Despite the adverse environment during this study, there were no reported cases of heat-related disorders. Yet, these findings quantify and illustrate the environmental stress during the investigation, and no significant interaction suggests that the climatic surroundings were similar for both Ramadan and non-Ramadan periods of investigation.

There was a significant variation between urine osmolality taken in Ramadan (825 mOsmol/kg H_2O) and non-Ramadan (707 mOsmol/kg H_2O), indicating that pre-training dehydration was greater during Ramadan in contrast to non-Ramadan, and supporting the findings of previous investigators (Angel *et al.*, 1975; Husain *et al.*, 1987; Hallak *et al.*, 1988). There was also a significant reduction in urine osmolality between weeks 1 and 4 of Ramadan; this observation supports the work of Sweileh *et al.*,(1992) and Ramadan and co-workers, (1999). The reduced dehydration levels over the weeks of Ramadan are thought to be accompanied by enhanced water retention by the kidneys, and an increase in water consumption during the night as Ramadan progresses. However, 825 mOsmol/kg H_2O is well into the warning category (Osmocheck guidelines) with several players arriving for training over the danger 1000 mOsmol/kg H_2O level. The debilitative effects of the dehydration can be attenuated to some extent through rehydration strategies before, during and after activity (McGregor *et al.*, 1999a; Maughan and Shirreffs, 2004), and so it is imperative that Islamic players are aware of such procedures.

Despite a significant main effect for urine osmolality between Ramadan and non-Ramadan, there was no significant interaction between the weeks of the study. Osmolality levels during the first week of non-Ramadan (week-5) were similar to the final week of Ramadan (week-4), even with the opportunity to ingest fluids during daylight hours. The similar pre-training dehydration levels following the first week of the non-Ramadan phase highlight the slow readjustment back to a normal lifestyle post-Ramadan, particularly fluid ingestion outside of training.

Body fluid lost in training during Ramadan and after Ramadan was not statistically significant. The average weight (kg) of the players is 71 kg. Therefore, the mean losses for body fluid during training in Ramadan and non-Ramadan were 2.7% (1.93 l) and 2.2% (1.54 l), respectively. There was no significant difference between the weeks of Ramadan for body fluids lost during training, or significant interaction between the weeks. The sharp dip in body fluids lost during week-3 is likely to reflect the international match week and the reduced frequency, duration and intensity of training sessions among the players who were not playing for their country. The body fluid loss during training is similar to some of the observations made by Mustafa and Mohamed (1979) for matches. Fluid losses as little as 2% body weight can negatively influence performance and may result in a reduction in physical work potential (Murray, 1998).

The mean core temperature of the midfield players during training sessions in Ramadan and non-Ramadan were 38.42 and 38.54 °C, and peak temperatures of 39.53 as well as 40.62°C were recorded, respectively. This 0.14 °C mean difference between Ramadan and non-Ramadan was significant. Corris and co-workers (2004) found a 0.15-02 °C rise in body temperature for every 1% reduction in body mass during activity. Therefore if 0.14 °C is roughly associated with 1% reduction in body mass, for an average Qatari soccer player of 71 kg this value equates to 700 ml. Consequently, it is possible that an increase in heart rate of around 6 beats.min^{-1} would have been induced from the greater 0.14°C core temperatures. For every 1-litre of fluid loss during exercise, heart rate is increased by about 8 beats.min^{-1} with a corresponding 1.0 l min^{-1} decrease in cardiac output (Corris *et al.*, 2004).

The higher core temperatures observed in the players during the post-Ramadan period are likely to be the result of a simulated game that took place during analysis with no equivalent duration and intensity monitored during the Ramadan period. The different types of training session monitored were the result of training objectives often being changed last minute by the head coach.

Also, it was only possible to monitor core temperature on the day of pill consumption, as subjects excreted the heat sensor pill within 24 hours. Nevertheless the simulated match-play for 2 x 25 min (full size pitch), stimulated core temperatures of two midfield players to rise to 38.9± 0.94 °C. Many components of soccer performance will be adversely affected once core temperature increases above optimal level 38.3 to 38.5°C (Astrand and Rodhal, 1986), in particular high-intensity intermittent endurance activity capabilities.

There was a significant difference in core temperature between the weeks of Ramadan, weeks 1 and 2 were higher in contrast to weeks 3 and 4. This increase in core temperature is likely to be associated with the greater urine osmolality pre-training, and bodily fluids lost during training in the first two weeks, in contrast with the later weeks of Ramadan. A 1-2% body mass reduction is connected with a significant increase in rectal temperature in comparison to the same relative intensity in a hydrated state (Coris *et al.,* 2004). There was also a significant interaction in bódy core temperature with an increase between week 3 and 4 during Ramadan, compared with a respective decrease in non-Ramadan. This significant interaction of core temperature is likely to be associated with the inconsistent training objectives and consequently; different training intensities and volumes, the change in pre-training hydration status, and body fluid loss during training between the respective Ramadan and non-Ramadan observations.

9.5 Conclusion

It is imperative that soccer coaches recognize and take into consideration the habitual lifestyle adjustments associated with Ramadan in their training programme plan. There is a lack of research regarding circadian variation, chronic hydration status, and training programmes with Qatari soccer players during and after Ramadan. This investigation has attempted to address these phenomena, noting that bedtime, and wake-up times during Ramadan were delayed considerably. Further, sleep duration was also increased, peaking at 10 hours during week 4 of Ramadan. It was not until two weeks post-Ramadan that the sleep patterns returned to normal. Therefore during Ramadan, the sleep-wake cycle was akin to nocturnal shift work and circadian variation post-Ramadan was similar to eastward time zone travel with around a 5-hour advancement in wake-up time.

The WBGT is indicative of the extreme environment within Qatar which was not significantly different during training between both Ramadan and non-Ramadan observations. The osmolality measurements during Ramadan were significantly higher in contrast to the non-Ramadan phase, indicating that the players were dehydrated to a greater extent prior to the start of training. There was significant difference in urine osmolality between week-1 of Ramadan and week-4, which suggests that the daily rehydration strategies of the players improved as Ramadan progressed. The body fluids lost during training were substantial both before and after Ramadan. Players reported the first two weeks of training as being excessive; this was likely a result of no modifications to training intensity and quality, in association with additional stress from lifestyle changes and the consequences of intermittent fasting. Furthermore, the effects of pre-training dehydration, and degree of bodily fluids lost within soccer practices were also likely to have amplified the relative training vales (TRIMP score), which are dependent on heart rate.

The effects of the combination of lifestyle factors, chronic dehydration, and reduction in relative training intensity surrounding Ramadan have not been well researched. Therefore, they will be investigated further in Study-4 via soccer-specific performance field tests.

Chapter 6

Study 4: The effects of Ramadan on a soccer-specific field test battery.

10. 0. Introduction

Ramadan is a focal part of Islam. During each day of Ramadan between dawn and sunset nutritional abstinence is practiced. This intermittent fast will vary in daily duration depending on geographical location, time of year, and can last up to 18 hours. This period is regarded as one of empathy for those less fortunate, discipline, and goodwill. The ethos for fasting is spiritual purification, acts of worship, improvement of health, self-control, avoidance of sin, safeguard against demonic influences, and ensure passage into the afterlife. The Islamic population is considerable and accounts for approximately 18% (1 billion people) worldwide (Robinson, 1991; Malik *et al.*, 1996; Fazel, 1998; Burden, 2001: Roky *et al.*, 2001).

Several investigators have observed changes associated with sleep during Ramadan (Bahammam, 2005; Zerguini *et al.*, 2007) particularly regarding a delay in acrophase, bedtime, sleep latency and waking. The degree of delay in bedtime and waking with Qatari professional soccer players was quantified in study-3, with post-Ramadan sleep patterns akin to eastward time-travel. One of the main physiological effects of intermittent fasting during Ramadan is dehydration. There was a significant level of dehydration among the Qatari professionals found in study-3 prior to training, in contrast to non-Ramadan. Also, significant differences in urine osmolality were evident between the first and final week of Ramadan, suggesting adaptation and better rehydration strategies as Ramadan progresses. As well, calorie restriction has been suggested to be another nutritional problem many intermittent fasters experience (Brownell *et al.*, 1987). There is a shortage of investigations into the effects of Ramadan on exercise performance (Roky *et al.*, 2000), and few have involved elite sportspeople, especially soccer players.

Several researchers who have conducted studies on seasonal variation in exercise performance have noted marginal differences in aerobic measures during the year. Reilly and Thomas (1979) found that the only changes during a competitive soccer season were in muscular power, resting heart rate, reduced force expiratory flow using a battery of 26 tests. Casajus (2001) reported no change in aerobic power of Spanish soccer professionals between September and February. Also, athletes of moderate to high levels with adequately developed aerobic capabilities typically display no seasonal variations in respiratory measures (Koutedakis, 1995). However, Casajus (2001) has noted significant differences in anaerobic running speed and heart rate (12.4 vs 13.1 $km.h^{-1}$) (HR 164 vs 168 $beats.min^{-1}$), respectively. Furthermore, Green and Houston (1975) reported that competitive ice-hockey players improved their maximal anaerobic capacity and power during a season by 16 and 5%, respectively. In contrast to maintenance or an increase in performance capacities, soccer fitness components also have the potential to diminish in a relatively short period of time. Empirical evidence from soccer coaches in Qatar is that during the 4-week intermittent fast, the daily diminished ability to sustain or tolerate high-intensity workloads, regular dehydration, lifestyle adjustments, and extreme environments, hinder the quality and effectiveness of training.

One of the key negative responses that can transpire with an insufficient training stimulus over 4 weeks or less is a reversal of training adaptations or a detraining effect (Mujika and Padilla, 2000). A greater understanding of the specific outcomes of intermittent fasting over 4 weeks on the separate soccer-fitness components would assist in a systematic approach to addressing the potential negative performance consequences associated with Ramadan, for future soccer-seasons among Islamic players.

The most essential physiological factors that determine a player's match-play capacity and highlight the degree of seasonal variation in performance can be evaluated using specific-soccer tests, conducted outside the competitive environment (Ekblom, 1986). The fundamental demands of soccer have long been established as a high-intensity intermittent game, and match-play is a combination of random, unpredictable patterns of play that vary from game to game.

The extremely complex nature of soccer means that no single test has the capacity to predict every aspect of physical ability required in the game (Svensson and Drust, 2005). There are many different protocols within exercise science used to evaluate similar fitness components applicable to soccer and numerous possibilities exist (Erith, 2004; Svenson and Drust, 2005).

A number of laboratory and field tests have been used and proposed to assess soccer players and stimulated much debate. Laboratory-based tests are the traditionally preferred mode of assessment within standard research in exercise science. However, the practicality of including frequent laboratory assessments within the professional soccer-season has proved to be problematic. The main problem with laboratory-based tests is that they can be very generic, lack specificity to soccer activities, and are time consuming. Laboratory-based evaluations also take the soccer players out of their natural environment and are not readily accessible to all clubs in terms of location, experienced personnel, and financial perspectives. Furthermore, Kemi and co-workers (2003) noted many laboratory personnel experience motivational problems with attracting elite soccer players for testing, and many coaches are reluctant or unable to employ this mode of evaluation. Those soccer teams that do subscribe to testing within laboratory settings, generally only do so during the pre-season phase. Consequently, only a partial snapshot of the physiology of a professional player is obtained, so comparisons can often be limited to between seasons (Svensson and Drust, 2005).

Conversely, field tests are more efficient and practical to administer, as large numbers can be accommodated simultaneously. Time is a big factor in professional soccer. Throughout the soccer season, the main focus is on playing games, training, and recovering. Skilful organsiation of the test procedures and discipline of coaches as well as players allow testing to be built into part of the day's training session with minimal disruption. Hence, other tactical, technical, and training drills can easily be incorporated within the same session following testing. Time required to complete a test component is another crucial factor. The number of tests that one is able to conduct may be compromised if an individual test takes too long, and it is desirable to collect as much data as possible in a soccer context (Ekblom, 1986).

Such cooperation with soccer coaches helps to promote more frequent testing, and so facilitate a greater understanding as well as quantification of players' physiological status during the soccer season. Field tests are also more specific to football and so, are more ecologically valid in contrast to laboratory tests (Svensson and Drust, 2005). Professional soccer coaches are constantly on the lookout for applicable field tests that facilitate them in measuring the fitness components of their players at the training ground (field conditions, Reilly and Williams, 2003). The battery of soccer-performance tests selected for this investigation was found to be robust in Study-2 and applicable for use within the hot environments. The purpose of this particular study is to investigate the influences of 4 weeks of intermittent fasting during Ramadan, on the discrete aspects of soccer-specific field test performance within the soccer season of Islamic players in Qatar.

10.1 Methods

10.1.2 Research design

The nature of this investigation means that a quasi-experimental design was applicable, using a within-subjects repeated measures procedure. The empirical data collected from this research are intended to be of direct value for practitioners. The natural soccer environment provides high ecologically validity. The subjects' performance scores collected during the non-Ramadan periods (pre-Ramadan/post-Ramadan) served as the control data, and were contrasted against information collected during the intervention of Ramadan. The battery of soccer tests was administered at 4 time points; (1) start of pre-season (17th, 18th, and 24th of July), (2) pre-Ramadan (4th, 5th, and 11th of September), (3) during Ramadan (25th, 26th September, and 2nd October), (4) post-Ramadan (29th/30th of October and 4th November). The holy month of Ramadan took place from the 24th September to 23rd October 2006. The Qatari soccer-league commenced on 16th September 2006.

10.1.3 Subjects

In this study 20 male professional Qatari soccer players were involved from the 1st team of Al-Ahli, soccer club. Altogether, 14 players were eligible for the complete 8-week analysis. The characteristics of the subjects were as follows and taken on the 4th September 2006 (12 days before the start of the season); age 25 ±3.4 years, height 1.75 ±0.07 m, body mass 71 ± 6.2 kg, body fat % 9.9 ±3.1 (4-skinfold sites, Durnin and Womersy, 1974), estimated $\dot{V}O_{2max}$ 52.3 ± 5.6 $ml.kg^{-1}.min^{-1}$ (Ramsbottom *et al.*, 1988) and maximum heart rate 192 ± 6 $beats.min^{-1}$ (Polar Team System, Finland).

10.1.4 Procedures

The protocols, equipment, calibration, and set-up for the 15 soccer-specific fitness tests used in this investigation can be found in Study-2 (Chapter 3). The YYIRT to volitional exhaustion (Krustrup *et al.,* 2003) was the only assessment excluded from this investigation, as it was found not to be robust in the heat in Study-2 (Chapter 3). During the previous season the majority of Al Ahli players (n =12) undertook the full test battery on two separate occasions, as part of the familiarisation process. Furthermore during each discrete test, there were always sub-maximal practice attempts by each player used as a warm-up for the task, re-familiarisation, and confirmation of rules prior to a maximal effort. The tests were set up, standardised and administered in accordance with procedures of study-2 (Chapter 3). All the test days were dry and free from rain, and tests were conducted around the same time of day at the start of training session (17:30 to 18:00 h), with the exception of Ramadan, which was roughly 21:00 h.

The full test battery was divided into three separate sessions, and then conducted over 3 days of testing. The first test session took place on the first training day of the week. It involved the YYIRT (Krustrup *et al.,* 2003) warm-up for 9 min, followed by tests that predominantly involved the immediate alactic energy supply and phosphocreatine, since recovery is relatively quick and residual fatigue is low (Hultman *et al.,* 1983).

The order of the performance tests in session-one was:- 10-m single-leg hop left and right, backward speed 10-m, speed 10-m 30-m and *flying* 20-m and Zig-Zag agility 20-m left and right (Buttifant and Graham, 1999). Test session-two was on the following day and began with a standardised warm-up (start of level-6 of the MSFT Ramsbottom *et al.* (1988)) followed by the standing broad jump, counter-movement jump and anaerobic capacity (LAST) (Chapter 2). Test session three was carried out on the first training day during the following week. After the standardised warm-up (start of level-6 of the MSFT Ramsbottom *et al.* (1988)) the test order involved rocket jump, counter-movement jump without the use of arms, and finally MSFT for estimating $\dot{V}O_{2\max}$ (Ramsbottom *et al.* 1988).

Following consultation with the medical and coaching staff, it was decided that the single-leg hop tests, sprints and agility work would be excluded from pre-season testing, to reduce the potential of injury: The transisitional off-season for Al Ahli players was largely unaccounted for and so fitness status of the players was unknown also, severe reductions in players' flexibility and range of motion were very apparent. Sprinting and explosive actions by team players with poor flexibility have been associated with hamstring injuries (Orchard *et al.,* 1997).

The medical staff at Al Ahli soccer club collected anthropometric data, and coaching staff assisted in the recording of performance data. Body fat percentage was taken using Durnin and Womersy's 4-site technique on the right hand side of a dry body (Durnin and Womersy (1974) with Harpenden Skinfold Calliper CE_{0120} (British Indicators, West Sussex), repeatability 0.20 mm, range 80.0 mm and accuracy 99.00%. Height was measured without shoes and socks. The heels were flat on the floor, with buttocks and scapular also touching the wall; the subject was facing straight ahead. Height was then taken from the highest point on the head. Players were weighed using Seca 761 mechanical floor scales (Hamburg, Germany) in dry underwear.

10.2 Statistical analysis

Descriptive statistics tables were used to highlight the mean values and spread of data between the subjects. To investigate the main effects between pre-season, pre-Ramadan, Ramadan, and post- Ramadan, a 4-level one-way repeated measures ANOVA was used, with Bonferroni correction. When significance was found, additional t-test calculations were systematically computed between the various time points of the season. Epsilon was used to correct the degrees of freedom based on guidelines of Girden (1992); significance was set at $P \leq 0.05$ and only data from players who participated in all four test sessions were computed. Where P values approached significance additional effect size calculations were employed to evaluate the degree (meaningfulness) of difference between the various time points of the season. The effect size calculations used were (Ramadan – pre-Ramadan)/pooled standard deviations), and (Ramadan – post-Ramadan)/pooled standard deviations where appropriate (Hopkins *et al.*, 1999).

10.3 Results

The environmental surroundings for each test session during the different time points of the season are quantified in Table XXIV. Anthropometric descriptive statistics of the players for the same respective stages of the season are presented in Table XXV. Heart rate data were taken to confirm that intensity of effort was similar and reached the required criteria for confirmation of valid estimates of aerobic power, YYIRT, and anaerobic capacity (LAST), see Table XXIII. The seasonal variation of the discrete soccer-specific performance results surrounding Ramadan can be found in Table XXIV.

Table XXIV: Environmental conditions during the test sessions.

Time of Season	(N)	Wet-Bulb Glob Temperature Mean	SD	Wind Speed km/h^{-1}	$m.s^{-1}$
1. Pre-Season	3	30.5	(0.9)	12.3	3.4
2. Pre-Ramadan	3	28.1	(1.0)	11.3	3.2
3. Ramadan	3	25.9	(1.1)	12.3	3.4
4. Post-Ramadan	3	25.0	(0.9)	14.3	4.0

N = number of days

Table XXV: Anthropometric changes at the four time-points of the season.

Time of Season	(N)	Body mass (kg) Mean	SD	Body Fat % Mean	SD
1. Pre-Season	18	72.00	(6)	11.2	(2)
2. Pre-Ramadan	18	71.20	(6)	9.9	(2)
3. Ramadan	18	70.3	(7)	9.6	(2)
4. Post-Ramadan	18	71.10	(6)	9.7	(3)

N = number of subjects

Table XXVI: Heart rates (beats.min^{-1}) for MSFT, YYIRT, and LAST during the season's testing sessions.

Time of Season	MSFT		YYIRT (9-min) $\%HR_{max}$		LAST			
						TT-1	TT-2	TT-3
	N	Mean SD	N	Mean SD	N	Mean SD	Mean SD	Mean SD
1. Pre-Season	14	193 (5)	14	92 (3)	12	178 (8)	182 (6)	186 (8)
2. Pre-Ramadan	14	192 (6)	14	84 (3)	12	178 (7)	181 (6)	185 (6)
3. Ramadan	14	191 (5)	14	88 (5)	12	199 (8)	182 (5)	183 (6)
4. Post-Ramadan	14	191 (5)	14	83 (3)	12	175 (7)	180 (6)	184 (6)

N = number of subjects
TT = 60-s time-trial

10.4 Seasonal variation in $\dot{V}O_{2max}$ (MSFT) Results

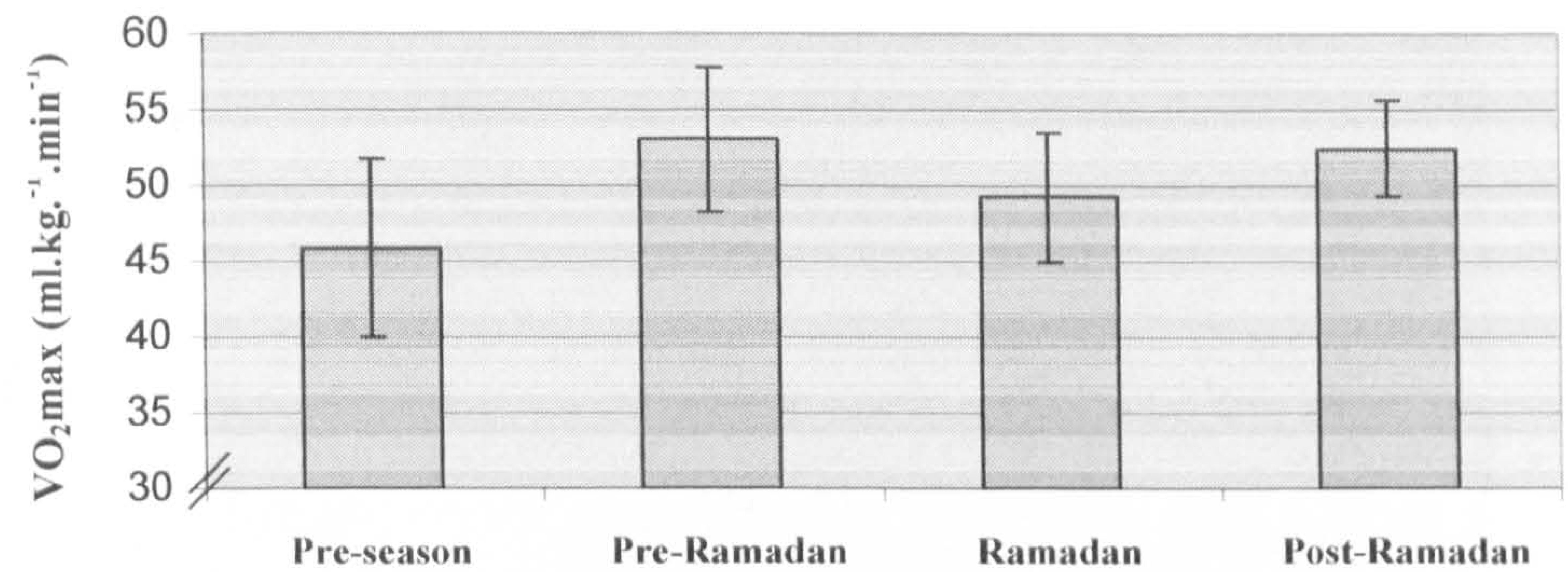


Figure 26. Mean ± of values for estimated $\dot{V}O_{2max}$ during the season surrounding Ramdan.

There was no significant difference ($F_{1.69, 21.94} = 2.0$; $P > 0.05$) between maximum heart rates taken during pre-season, pre-Ramadan, Ramadan, and Ramadan during the MSFT for estimating $\dot{V}O_{2max}$ (Ramsbottom *et al.* 1988). Heart rate values taken during all $\dot{V}O_{2max}$ assessments were within 10 beats of age-predicted maximum (195 ±3 beats.min^{-1}), and so all tests were considered valid measures of maximal exercise performance.

There was a significant change ($F_{1.92, 29.94} = 17.48$; $P < 0.05$) between estimated $\dot{V}O_{2max}$ values within the seasonal test sessions (Figure 26). Significant increases were evident between pre-season and pre-Ramadan (P = 0.001), and pre-season and post-Ramdan (P = 0.001). There was no significant difference between pre-season and Ramadan (P = 0.238), A significant reduction was observed in estimated $\dot{V}O_{2max}$ values, between pre-Ramadan and Ramadan (P = 0.018). Following the holy month, there was a signifcant increase in estimated $\dot{V}O_{2max}$ values aerobic power (P= 0.033).

Between pre-Ramadan and post-Ramadan (control test sessions) there was no signifcant difference (P= 0.471). The mean estimated $\dot{V}O_{2max}$ values were 53.1 ±4.7 and 52.5 ± 3.1 ml.kg^{-1}.min^{-1} for pre-Ramadan and post-Ramadan, respectively; consequently, the effect size (0.92) suggests a large reduction in aerobic power.

10.5 Seasonal variation of sub-maximal aerobic performance (YYIRT 9-minutes)

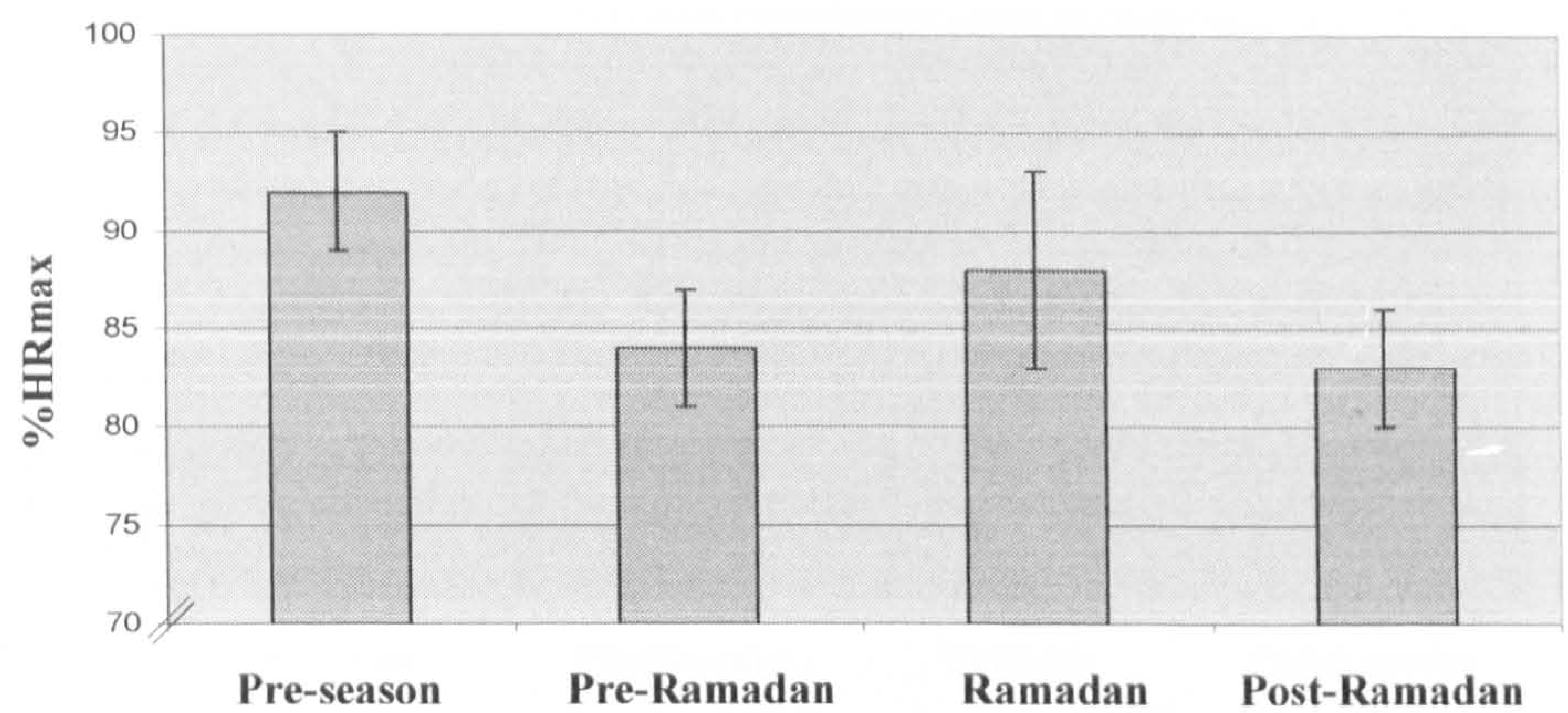


Figure 27. Performance of YYIRT (9-min) during the season surrounding Ramadan.

For sub-maximal aerobic perofmance as measured by the YYIRT (9 min) (Krustrup *et al.*, 2003), there was a significant difference ($F_{1.86,\ 22.03} = 31.20$; $P < 0.05$) (Figure 27) between test sessions within the season. In comparison with pre-season, there were significant reductions in pre-Ramadan, Ramadan, and post-Ramadan (P = 0.001, 0.004, and 0.001) assessments, respectively. There was no significant change in $\%HR_{max}$ between pre-Ramadan and Ramadan (P = 0.112), but there was a significant reduction between Ramadan and post-Ramadan (P = 0.042).

There was no signifcant difference (P= 0.078) between pre-Ramadan and post-Ramadan (the control test sessions). The mean $\%HR_{max}$ was 84 ±3 and 83 ± 2.5 for pre-Ramadan and post-Ramadan, respectively; consequently, the effect size of (0.67) indicate a moderate decrease in $\%HR_{max}$.

10.6 Seasonal variation in anerobic capacity LAST results

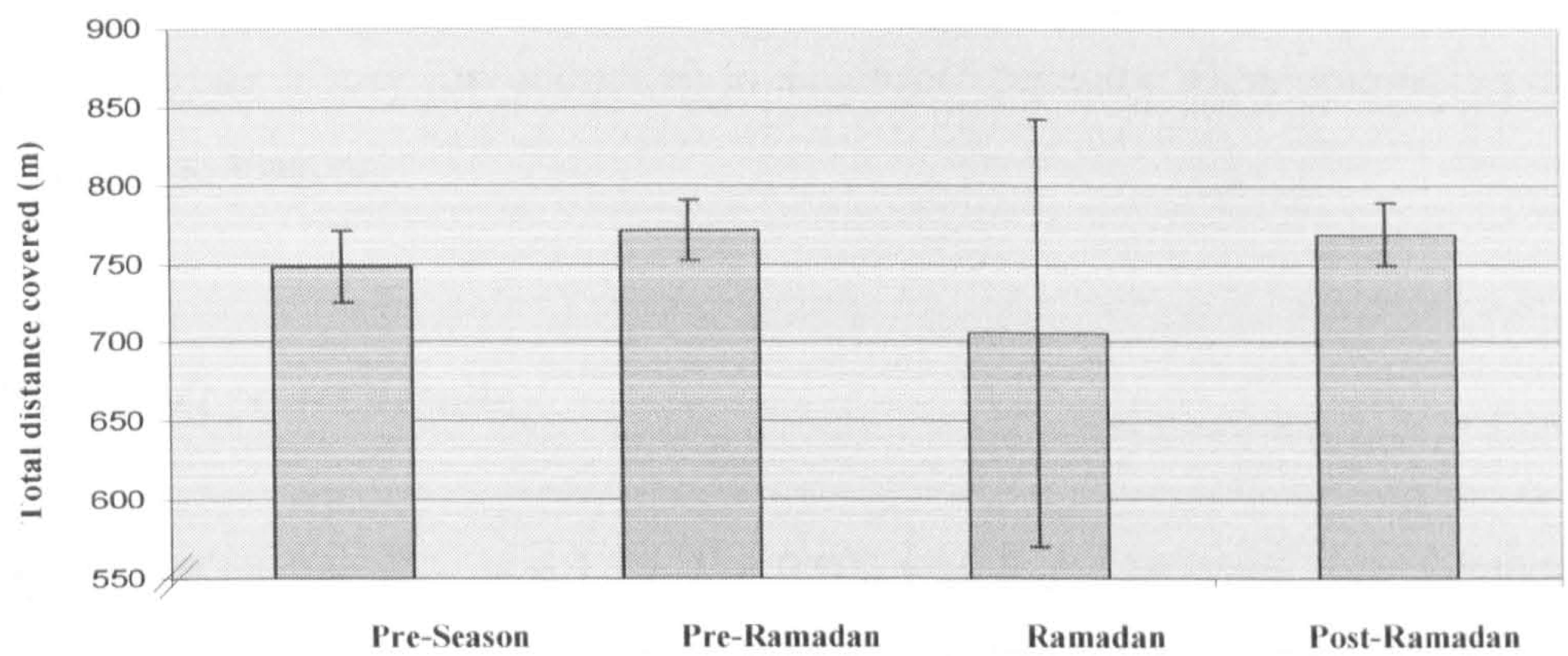


Figure 28. Mean ± of values for anaerobic capacity during the season surrounding Ramdan.

There were no significant differences ($F_{2.11, 23.2} = 1.19$ $P > 0.05$; $F_{3, 33.1} = 1.46$ $P > 0.05$; $F_{1.8, 19.3} = 0.924$ $P > 0.05$) between heart rates measured in time trials 1, 2, and 3 during pre-season, pre-Ramadan, Ramadan, and post-ramadan, respectively. Therefore, all three 60-s time trials for all four LAST assessments within the season were considered as valid mesurements of ananerobic capacity.

There was a significant change ($F_{2.18, 24} = 14.74$; $P < 0.05$) between the LAST scores taken surrounding the Ramadan period (Figure 28). There was a significant increase (P = 0.001) between pre-season and pre-Ramadan, as well as pre-season and post-Ramadan (P = 0.001). No significant difference (P = 0.101) was found between pre-Ramadan and Ramadan, the mean total distance covered in the LAST was 771 ±19 m and 706 ±136 m; as a result, the effect size of (-0.84) suggest a large reduction in anaerobic capacity during Ramadan. Following Ramadan, no signifcant change (P= 0.111) was noted between Ramadan and post-Ramadan, the mean total distance covered in the LAST was 706 ±136 m and 769 ±20 m; consequently, the effect size of 0.81 suggests a large improvement in anaerobic capacity after Ramadan.

Between pre-Ramadan and post-Ramadan (control test sessions) there was no signifcant difference (P = 0.605); The mean total distance covered in the LAST was 771 ± 19 and 769 ±20 for pre-Ramadan and post-Ramadan, respectively; consequently, the effect size of 0.09 suggests a very low reduction in anaerobic capacity when comparing the control periods of the season.

10.7 Vertical power results

A significant change ($F_{3, 39} = 1.19$; $P < 0.05$) was found between rocket-jumps taken at the 4 stages of the season, there were increases between pre-season and Ramadan (P = 0.007), and pre-season and post-Ramadan (P = 0.013). For the CMJNA, a significant differnce was also evident ($F_{3, 39} = 9.016$; $P < 0.05$), with a similar improvement occurring between pre-season and post-Ramadan (P = 0.007). In accordance with the other vertical power assessments, CMJ was also significantly different ($F_{3, 39} = 7.355$; $P < 0.05$) with an increase between pre-season and Ramadan (P = 0.13), and pre-season and post-Ramadan (P = 0.42).

10. 8 Horizontal power

No significant variations ($F_{3, 39} = 9.016$; $P > 0.05$) were found with static horizontal power as evulated by SBJ, between pre-season, pre-Ramadan, Ramadan and post-Ramadan. The mean values were 2.51 ± 0.18 m for pre-Ramadan and 2.54 ± 0.17 m for Ramadan; thus, the low effect size (0.17) indicated that the increase in static horizontal power during Ramadan was small. Furthermore when the post-Ramadan values were contrasted against Ramadan; post-Ramadan = 2.53 ± 0.17 m a low effect size (0.06) was produced and suggest after Ramadan the reduction of horizontal power was very low.

There were no significant changes for dynamic horizontal power, 10-m single-leg hops (left and right) ($F_{1.94, 25.22} = 3.264$; $P > 0.05$; $F_{2, 26} = 3.183$; $P > 0.05$), respectively measured at pre-Ramadan, during Ramadan and post-Ramadan. The mean values for left and right single-leg hops pre-Ramadan were 2.32 ± 0.20 s and 2.33 ± 0.16 s, and during Ramadan were 2.29 ±0.17 s and 2.32 ± 0.17 s respectively; consequently, the effect sizes were (-0.15) and (-0.06) and suggest a very small decrease in dynamic horizontal power time during Ramadan. After the holy month, the mean values taken for left and right single-leg hop post-Ramadan (2.23 ± 0.17 s and 2.26 ± 0.15 s) were compared with Ramadan; as a result the effect sizes 0.27 and 0.38 indicate a low and and a low to moderate reduction in time for horizontal power.

10. 9 Speed

Backward speed was measured over 10 m, but there were no significant differences ($F_{2, 26} = 3.183$; $P > 0.05$) in values observed between pre-Ramadan, Ramadan, and post-Ramadan. The mean time pre-Ramadan was 2.32 s ± 0.11 s and during Ramadan was 2.31 ± 0.13 s; the effect size was (-0.08) and indicate a minor reduction in backward speed during Ramadan. Accordingly, 10-m backward post-Ramadan mean time 2.28 s ± 0.14 s was contrasted with Ramadan, producing a low effect size (0.23) and indicating after Ramadan there was a small reduction in 10-m backward speed time.

There was a significant reduction ($F_{1.83, 23.71} = 0.746$; $P < 0.05$) within the seasonal evaluations in the 10-m sprint test; the difference was (0.06-s) between pre-Ramadan and post-Ramadan and significant at ($P = 0.015$). There were no significant changes in 30-m sprint ($F_{1.46, 18.9} = 0.124$; $P > 0.05$) across the seasonal assessments. The mean values pre-Ramadan were 4.20 ± 0.15 s and during Ramadan 4.21 ± 0.25 s; as a result the effect size was (0.05) and suggest a slight increase in 30-m sprint time during Ramadan. The post-Ramadan 30-m sprint time was 4.18 ± 0.20 s and when contrasted with the 30-m sprint time taken during Ramadan produced a low effect size (0.23), indicating the reduction in time of 30-m speed following Ramadan was small.

With regard *flying*-20-m sprint, there was no significant change in times surrounding Ramadan ($F_{1.49, 19.31} = 1.080$; $P > 0.05$). Pre-Ramadan measurements for flying-20m were 2.48 ± 0.13 s and in Ramadan 2.57 ± 0.22 s; as a result the effect size was 0.51 and suggests a moderate increase in flying-20 m time during Ramadan. Following Ramadan the time for flying-20 m speed was 2.52 ± 0.17 s; consequently, the effect size was 0.26 and suggests a small reduction in flying-20 m times in contrast to Ramadan.

10. 10 Agility

For the 20-m agility left and right starts taken pre-Ramadan, within Ramadan, and post-Ramadan, no significant differences were evident ($F_{1.48, 19.28} = 3.815$; $P > 0.05$, ($F_{2, 26} = 0.96$; $P > 0.05$). The pre-Ramadan mean times for 20-m agility left and right were 4.15 ± 0.13 s and 4.06 ± 0.17 s respectively; in comparison, left and right times measured during Ramadan were 4.08 ± 0.16 s and 4.07 ± 0.18 s; therefore, there was a large effect size in agility left (-0.84) and indicate a marked reducction in left start 20-m zig-zag time taken during ramadan. However, the effect size for the right side start was -0.01 and suggests a marginal increase in 20-m zig-zag time in Ramadan. Following Ramadan the left and right agility times recorded were 4.10 ± 0.12 s and 4.08 ± 0.13 s respectively; consequently, the effect sizes produced were low (-0.14) and (-0.06) and indicate a slight increase in 20-m zig zag performance after Ramadan in comparion with Ramadan.

10.11 Results Summary

Table XXVII: Summary of the seasonal variation of the soccer-specific performance scores.

Test	(N)	Pre-Season Mean	Pre-Season SD	Pre-Ramadan Mean	Pre-Ramadan SD	PreR ES	Ramadan Mean	Ramadan SD	Post-R ES	Post-Ramadan Mean	Post-Ramadan SD
1. MSFT ($\dot{V}O_2$ ml.kg^{-1}.min^{-1})	14	45.9	(5.9)	53.1*+	(4.7)	-0.87	49.2*	(4.3)	-0.85	52.5*	(3.1)
2. YYIRT (9-min %HR_{max})	14	92	(3)	84	(3)	0.85	88	(4.5)	1.2	83*+	(2.5)
3. LAST (m)	14	748	(23)	771*	(19)	-0.84	706	(136)	0.81	769	(20)
4. Rocket Jump (cm)	14	43.9	(4.4)	43.5	(5.0)	0.58	46.3*	(4.7)	-0.06	46.6*	(4.8)
5. CMJNA (cm)	14	46.4	(5.2)	45.1	(5.1)	0.65	48.5	(5.4)	-0.06	48.8*	(5.4)
6. CMJ (cm)	14	52.8	(7.0)	52.3	(5.8)	0.42	54.8*	(6.0)	-0.05	55.1*	(5.6)
7. SBJ (m)	14	2.48	(0.19)	2.51	(0.18)	0.17	2.54	(0.17)	0.06	2.53	(0.17)
8. 10-m SLHL (s)	14	NT		2.32	(0.20)	-0.15	2.29	(0.20)	0.27	2.23	(0.17)
9. 10-mSLHR (s)	14	NT		2.33	(0.16)	-0.06	2.32	(0.17)	0.38	2.26	(0.15)
10.10-m Sprint (s)	14	NT		1.72	(0.11)	0.38	1.68	(0.1)	0.22	1.66*	(0.08)
11.30-m Sprint (s)	14	NT		4.20	(0.15)	0.05	4.21	(0.25)	0.13	4.18	(0.20)
12. Flying 20-m (s)	14	NT		2.48	(0.13)	0.51	2.57	(0.22)	0.26	2.52	(0.17)
13. Backwards 10-m (s)	14	NT		2.32	(0.11)	-0.08	2.31	(0.13)	0.23	2.28	(0.14)
14. 20-m ZZ Agility L (s)	14	NT		4.15	(0.13)	-0.84	4.08	(0.16)	-0.14	4.10	(0.12)
15. 20-m ZZ Agility R (s)	14	NT		4.06	(0.17)	-0.01	4.07	(0.18)	-0.06	4.08	(0.13)

Note:
N= Number of subjects
NT = No Test
ES = effect size
PreR= pre-Ramadan
Post-R = post-Ramadan
Anaerobic capacity LAST units = total distance-metres
Vertical-power units = cm
Horizontal power units SBJ = m
Speed and agility units = seconds
*= Indicates signifcant difference from pre-season
+ = Indicates signifcancant difference between non-Ramadan and Ramadan

10.12 Discussion

The MSFT (Ramsbottom *et al.*, 1988) proved to be a sensitive indicator of aerobic power for soccer players, highlighting significant changes between pre-season and pre-Ramadan (post-pre season) $\dot{V}O_{2max}$ values. The difference between pre-Ramadan and Ramadan $\dot{V}O_{2max}$ testing was roughly three weeks, during which time the Al-Ahli players were training and playing full-time. A key finding was the significant reduction observed in aerobic power of the Qatari soccer players during Ramadan. This significant decrease in estimated $\dot{V}O_{2max}$ values from pre-Ramadan to within Ramadan, is likely to be associated with the high degree of pre-training dehydration status. During Study-3, urine analysis of the players during Ramadan indicated values of 898 ± 170 mOsmol/kg H_2O. Prior dehydration has been reported to hinder high-intensity prolonged performance (Maughan and Shirreffs, 2004). The reduction of $\dot{V}O_{2max}$ values supports the observations of Zerguini and co-workers (2007) who also found that absolute endurance performance during Ramadan was reduced by 20% below baseline values, among soccer players from Algiers. Additionally, Sweileh and colleagues (1992) have also reported a fall in $\dot{V}O_{2max}$ values between pre-Ramadan and the first week of Ramadan using sedentary subjects. Negative energy balance as well as chronic sleep disturbance can also contribute to a reduction in endurance performance (Martin, 1981; Reilly and Piercy, 1994).

There was a significant increase in estimated $\dot{V}O_{2max}$ values between Ramadan and post-Ramadan, and this phenomenon suggests that a recovery in aerobic power was made between these sessions. Furthermore, the significantly lower degree of dehydration and return to normal of pre-training hydration levels of the players (618 ± 164 mOsmol/kg H_2O) noted post-Ramadan in Study-3, support the notion that the reduction of aerobic power performance during Ramadan was associated with dehydration. There was no significant difference in estimated $\dot{V}O_{2max}$ between the control data assessments (pre- and post-Ramadan).

However, the effect size between pre-Ramadan and post-Ramadan was large (0.92), and although a recovery in aerobic power was made post-Ramadan, aerobic power performance was still below pre-Ramadan levels. This slight decrease in aerobic power post-Ramadan is consistent with observations made by Zerguini and co-workers (2007) who reported reductions of 10% from pre-Ramadan baseline values, two weeks post-Ramadan. These decreases in estimated $\dot{V}O_{2max}$ values may be associated with a detraining effect or reversibility of aerobic power immediately post-Ramadan.

Maximal oxygen uptake is an important factor that determines the upper limit in endurance performance (Bassett and Howley, 1997). Elite level soccer players generally possess a relatively high $\dot{V}O_{2max}$. A high rank-order correlation between $\dot{V}O_{2max}$ and final position in the league has been found in both Hungarian players and Norwegian players (Apor, 1988; Wisloff *et al.,* 1998). Furthermore improvements in $\dot{V}O_{2max}$ following training programmes have been associated with an increase in distance covered, work-intensity, number of sprints, and involvements with a ball during a soccer-match (Helgerud *et al.,* 2001; McMillian *et al.,* 2005). Therefore it is logical to assume that a reduction in aerobic power either during or post-Ramadan could be extremely costly for an Islamic soccer team, especially if competing against non-fasting players in an important competition such as World-Cup qualification.

The YYIRT (Krustrup *et al.,* 2003) served a dual purpose of a standardised soccer-specific warm-up for day 1 of testing, and also as a sub-maximal aerobic test. There was a significant reduction in % HR_{max} at 9 min of the YYIRT between pre-season and pre-Ramadan, Ramadan, and post-Ramadan. These results indicate that the YYIRT is a sensitive measure of sub-maximal aerobic fitness, and supports the findings of Krustrup and co-workers (2003) who developed the YYIRT and reported that the test is capable of detecting seasonal variations in soccer players.

Despite the absence of a significant difference in % HR_{max} at 9 min of the YYIRT between pre-Ramadan and Ramadan, the large effect size (0.85) illustrates that during Ramadan there was a classical elevation of heart rate in association with a considerable degree of dehydration during a standardised sub-maximal exercise protocol (Bangsbo, 2003). These findings suggest that during soccer practice and matches within Ramadan, the Al Ahli players' sub-maximal performance capabilities were compromised. When exercising in a dehydrated condition, the decrease in plasma volume and subsequently cardiac output reduces the oxygen supply to metabolic processes within muscle. Consequently, the heart beats faster to attain or sustain a similar absolute intensity of activity, in contrast to a euhydrated state. This process leads to an acceleration of glycogen depletion and relatively premature fatigue (Brooks *et al.,* 1995).

Conversely, there was a significant fall in % HR_{max} during the sub-maximal YYIRT between Ramadan and post-Ramadan. These findings were accompanpied by a significant reduction in urine osmolality pre-training during the post-Ramadan phase (Study-3). These slightly lower heart rates observed post-Ramadan are possibly the result of a classic training effect, a reduced heart rate to a standardised exercise intensity following several exercise sessions in a relatively short period of time. Other investigators (Ramadan and Barac-Nieto, 2000) have also reported lower heart rate responses to sub-maximal exercise post-Ramadan.

There was a significant change in total distance covered of the LAST between pre-season and pre-Ramadan which indicates that the test is sensitive to detect variation in anaerobic capacity performance. There were no significant differences in total distances covered in the LAST between pre-Ramadan, Ramadan, and post- Ramadan. However, there was a large negative effect size between pre-Ramadan and Ramadan (-0.84) that was still apparent post-Ramadan (-0.81); this effect size shows that there was a meaningful reduction between LAST scores during Ramadan, Figure 34 illustrating this decrease of ananerobic capacity. Furthermore, during the LAST assessments within Ramadan, two players were unable to continue from sensations of dizziness, nausea, lack of energy, and fatigue these symptoms are commonly experienced with hypoglycaemia (Shanks *et al.,* 1994).

These two early withdrawls of ananerobic capcity assessments during Ramadan produced relatively large standard deviations on the group mean data; the respective total distances covered by both players were roughly half the distance of their pre- and post-Ramadan tests. Such a drop-out rate during the ananerobic capacity test highlights that such high-intensity work is not very well tolerated by some intermittent fasters! Therefore it is reasonable to suggest that during a game or training within Ramadan, the ability of some Al Ahli players to perform high-tempo bouts of play was compromised. Saltin (1973) reported that low glycogen levels pre-soccer match hinder high-intensity activity during match-play. High-intensity activity and recovery are two important aspects of modern soccer games, with elite soccer professionals capable of producing greater distances and recovering faster in comparison to moderate professional players (Mohr *et al.*, 2003). Post-Ramadan LAST performances improved back to almost pre-Ramadan levels. The primary energy system to perform and sustain high-intensity activity is anaerobic glycolysis. The reduction in LAST performance during Ramadan may be associated with a poor consumption of carbohydrate-based foods by the players and consequently glycogen content within muscle would be low.

For vertical power assessments, significant improvements were observed from pre-season to Ramadan and post-Ramadan, respectively in all three separate jumps. Pre-training dehydration staus is likely to have been influential in this rise of vertical power during Ramadan, since a player can be slightly lighter, but retain the same power output (Maughan, 2003; Reilly and Waterhouse, 2005). Post-Ramadan the retention of the increase in vertical power in association with a return to a euhydrated state, is possibly associated with the type of soccer-conditioning performed around that time. The introduction of plyometric activity to the soccer-training programme during Ramadan may have had an effect on the maintenance and improved vertical power values. Short-term plyometric training can increase athletic performance (Diallo *et al.*, 2001).

There were no significant differences in horizontal power measurements (SBJ and 10-m SLH left/right) between all seasonal test sessions. There was a slight increase in SBJ, and similar to the increase in vertical power is likely to be assocaited with the dehydrated state and a lighter body weight of the player. The 10-m SLH effect size was relatively low across the Ramadan measurements, indicating no real change in this variable.

The only significant difference with regards the speed assessments was between pre-Ramadan and post-Ramadan 10-m sprint times, with a reduction of 0.06-s in time following the holy month (1.72-s to 1.66-s). Posssible explanations for this reduction in time include biological variation of performance (preparedness) (Zatsiorsky, 1995) or performance improvement. The maximal running speed during a game has been found to be around 9 m. s^{-1} (Luhtanen, 1994). Therefore, a 0.06-s reduction would amount to around 0.54 m in distance, which can be vital in soccer over a short sprint. No significant seasonal variation surrounding Ramadan was evident in the agility involving both a left and right-cut to start. Possible explanations as to why the improvements observed in 10-m sprint did not also manifest in other speed distances, may be related to training specificity (Smith, 2003). The speed conditioning conducted around that time mainly involved only short-sprints around 1-10 m and footwork drills, seldom were any longer sprints or similar agility drills performed.

10. 13 Conclusion

Professional Islamic soccer players must still train and compete throughout the 4 weeks of intermittent-fasting during the holy month of Ramadan. Improved understanding of the influences of fasting during Ramadan would assist professional coaches with their preparation of soccer teams for both training and playing games around this religious festival. A battery of soccer-specific field tests was employed to evaluate the seasonal variation of discrete soccer-fitness components surrounding Ramadan, in an attempt to identify any crucial changes. To conclude, the key performance changes observed surrounding Ramadan were as follows:

1a. Significant reduction in aerobic power occurred during Ramadan.

1b. Considerable improvement of aerobic power was found after Ramadan however, estimated $\dot{V}O_{2_{max}}$ measurements were still below pre-Ramadan values.

2.a There was a marked increase in $\%HR_{max}$ taken during the sub-maximal aerobic assessment in Ramadan.

2.b Significant reduction occurred in $\%HR_{max}$ in sub-maximal aerobic measurements post-Ramadan in comparison with Ramadan.

3a. Anaerobic capacity was hindered during Ramadan and high-intensity anaerobic activity was not tolerated very well in some players.

3b. Post-Ramadan anaerobic capacity improved back to around pre-Ramadan level.

4. Vertical power and 10-m speed were improved during Ramadan.

Chapter 7

Synthesis of findings

11.0 General Overview

The studies in this thesis were conducted to investigate the influence of 4 weeks of intermittent-fasting during the holy month of Ramadan on professional Islamic soccer players. Experienced soccer coaches within Qatar subjectively report that the 4-week intermittent fast during Ramadan impedes the quality and quantity of training, as well as affecting match play. Improved understanding of the consequences of intermittent fasting on soccer-fitness components would assist in a systematic approach to addressing potential negative performance effects associated with Ramadan in future soccer-seasons. Today there is no established complete battery of soccer-specific field tests and guidelines for the fitness coach/sports scientist to follow in the professional world of soccer. Therefore before the research problem could be addressed, a comprehensive battery of field-tests based around the soccer testing model of Ekblom, (1986) and the discrete fitness components described by Bangsbo (2003) was compiled.

11.1 Realisation of aims

11.2 Study-1

The options for suitable soccer-specific anaerobic capacity tests were inadequate (Bangsbo, 1997; Hoff and Helgeurd, 2004; Sands *et al.*, 2004). A high anaerobic capacity is a crucial factor to performing and sustaining repeated high-intensity activities, which are important aspects of the modern game (Reilly and Williams, 2003; Mohr *et al.*, 2003). Therefore, it was logical that a soccer-specific anaerobic capacity field-test be included within the test battery; this rationale provided the purpose for Study-1 which piloted and found the *Liverpool Anaerobic Speed Test* or LAST to be reliable, valid, and practical. The LAST requires two familiarisation sessions to reduce systematic bias and habituate players with procedures of the test. The total measurement error (95% ratio of LOA) of the LAST was 2.5% (± 18 m), and peak blood lactate values produced were 17.6 $mmol.l^{-1}$, which were greater than the 14.7 $mmol.l^{-1}$ criteria set for maximal anaerobic effort prior to the study. Practically, the LAST design was time-efficient, evaluating large numbers of players relatively quickly, and the procedure can be easily adapted to soccer-conditioning drills (Wilson, 2001; Bangsbo, 2003; Reilly, 2003). Hence, the LAST was included in the soccer-specific battery of field tests, which then provided a comprehensive analysis of the separate components of soccer performance.

However, there are still other aspects of soccer fitness that would also benefit from further investigation and the development of an appropriate test such as, the repeated sprint ability fitness component. Today there are several tests that claim to evaluate a form of repeated sprint ability (Bangsbo, 1994; Verheijen, 1998), but the energy systems involved, total distance covered, number of repetitions and recovery between sprints varies considerably. Furthermore, there is no clear definition of test criteria for repeated sprint ability. The practicality of conducting the current repeated sprint ability tests can be time consuming (> 20 min) and may compromise the number of assessments possible in a test session.

11.3 Testing, environment and soccer practice

In order to reduce the possibility of making erroneous conclusions regarding the main focus of the thesis (*influence of intermittent fasting on soccer performance tests* (study-4)) and to provide greater insight to training responses surrounding Ramadan, a methodical approach was necessary to account for the external environmental and training factors.

11.4 Study-2

The available facilities for conducting the soccer performance tests with Al-Ahli-sports club Qatar were the grass soccer-field at the training ground, a scenario typical of many soccer clubs worldwide. Environmental temperatures within Qatar can fluctuate during various times of the season, and at times be quite adverse. The purpose of Study-2 was to investigate how robust the discrete soccer-specific field tests were that potentially would be used for the main focus of this thesis in Study-4. This aim of Study-2 was realised via a repeated measures counter-balanced design involving a controlled indoor (sports-hall) and outdoor (soccer-field) environment. The key finding from Study-2 was a significant reduction of 19% in maximal performance during the outdoor YYIRT (Krustrup *et al.*, 2003), despite the subjects attaining similar maximal heart rates as the indoor YYIRT. Consequently, the YYIRT to volitional exhaustion was excluded from the battery of tests used in Study-4. The reason was that it would be difficult to differentiate the degree of any potential change in test performance connected with environment surroundings, from possible physiological variation in the YYIRT associated with consequences of intermittent fasting. The remaining soccer-specific field tests were found to be robust for application in the heat.

11.5 Study-3

The aim of Study-3 was to conduct a qualitative investigation to observe current soccer-practice and related factors surrounding training; this included bedtime, wake-up time, sleep duration, environmental conditions, pre-training dehydration, body fluids lost during training, body-core temperature, and relative training intensity.

Circadian Variation

There is limited research associated with circadian rhythm variations during and outside Ramadan of professional soccer players. So, the habitual lifestyle changes of professional Qatari soccer players were investigated in Study-3; a significant delay of around 198 min was found in bedtime, an increase of 297 min for wake-up time, and sleep duration was also lengthened by 99 min during Ramadan. The wake-up time of mid-afternoon during Ramadan for the Islamic soccer players was a sensitive finding, as some devout Muslims may not consider such a routine as adhering to the ethos of nutritional abstinence during this religious period. Following Ramadan, the reversal of these sleep modifications of bedtime and wake-up time was slow and it was not until roughly two weeks post-Ramadan that the sleep-wakefulness cycle returned back to normal non-Ramadan patterns. This period immediately post-Ramadan was suggested to be akin to the disturbance of circadian rhythms due to eastward time travel, as wake-up time was advanced by roughly 5 hours. The most severe symptoms of jet-lag are experienced with eastward time travel (Reilly and Waterhouse, 2007).

Environment and dehydration

The environmental stress found during the 8-week training period around Ramadan was not distinctly different between the respective Ramadan and non-Ramadan periods, but it was unfavourable for soccer training (WBGT 25.7 °C to 24.6°C), respectively. In such climatic surroundings, it is recommended that practice be modified considerably and closely monitored for heat stress. Furthermore during week-4 of Ramadan, WBGT was 28 °C, a scale at which practices or games are recommended to be cancelled (Shephard, 1999). Yet, no consideration was made regarding the environment and training continued as normal, as per directives of the head coach.

The pre-training dehydration condition of the players during Ramadan was considerably greater than non-Ramadan and well into the warning category of the Osmocheck guidelines (Vitech Scientific, West Sussex). This observation of dehydration surrounding Ramadan is in accord with previous investigations (Angel *et al.,* 1975; Husain *et al.,* 1987; Hallak *et al.,* 1988). Furthermore, there was also a noteworthy reduction in urine osmolality between weeks 1 to 4 of Ramadan, which is a trend that has also been observed previously and associated with a greater water intake and fluid retention (Sweileh *et al.,* 1992). Despite a significant main effect of urine osmolality between Ramadan and non-Ramadan weeks, there was no significant interaction between the weeks of the respective training period; this result may be due to a generally slow readjustment back to normal routine and lifestyle habits post-Ramadan.

Fluid loss

The mean body fluids lost during training were not statistically different between Ramadan and non-Ramadan weeks and were 2.7% (1.93 kg) and 2.2% (1.54 kg), respectively. The 0.5% difference in body fluids lost between the two training periods is probably associated with the slightly higher temperatures during Ramadan and the longer duration of training sessions conducted by the head coach. Furthermore the considerable fluid loss of the Al Ahli players during training in combination with the significantly greater urine osmolality values pre-training, highlights the necessity for rehydration strategies surrounding Ramadan for Qatari professional players.

Core Temperature

During training, significantly higher core temperatures in two midfield players were observed during the non-Ramadan period, this occurrence is likely to be a product of inconsistencies of the intensities of the training sessions involved in the analysis that were beyond the control of the author (see Limitations).

Soccer Training

Workload conducted during soccer practice can be quantified for each player based around a simple calculation that separates work intensities (50-100%) into heart rate zones (1-5) which, is then multiplied by the duration of exercise minutes spent in each respective heart zone; consequently, a modified TRIMP value (training impulse) (Table II) is produced for the training session (Brandon, 2005). There was no significant difference for the Modified TRIMP Values (MTV) (heart rate zone x duration) between Ramadan and non-Ramadan weeks but the effect size was large and noteworthy problems occurred within the training programme during Ramadan. The head coach of Al Ahli was extremely cooperative regarding adaptation of training sessions on the days of testing, for the purpose of this investigation. The head coach generally failed to recognise the holistic effects of the environment and intermittent fasting on the players during Ramadan, and modify his training programme objectives accordingly. Consequently following only two weeks of Ramadan, problems developed between the players and head coach, regarding the players' physiological state in response to the lifestyle changes of Ramadan and soccer-practice aims and expectations.

Players were subjectively reporting heavy legs, tiredness, lack of motivation and energy. The average daily training session minutes within the first two weeks of Ramadan was typically 80-90 min. The head coach followed training objectives *"cookbook style"* used previously with other non-fasting teams involved in a higher standard of play (FC Sion, Switzerland, CS Safxien, Tunisia). While such a training strategy was not a major issue pre-Ramadan, the additional stress associated with lifestyle changes during Ramadan to this training schedule, was reported to be excessive by the players. Physiologically a relative increase in overload in combination with insufficient recovery would have not only retarded supercompensation and adaptation (Siff, 2003), this unbalanced training regimen appears to have led to symptoms suggestive of acute over-reaching (Isreal, 1958). Following intervention from the Arabic management of the club on behalf of the players, the head coach was persuaded to modify soccer practice. Consequently, the daily training volume was reduced to <60 min (Figure 17).

11.6 Study 4

The purpose of Study-4 was to enhance understanding of the effects of intermittent fasting during Ramadan on discrete soccer-fitness components. This information would in future seasons allow coaches to appreciate the potential negative training and performances outcomes of Islamic players that have been reported empirically by soccer coaches working in Qatar.

One of the key influences of intermittent fasting on soccer-fitness components during Ramadan was the significant drop in aerobic power values; this observation supports the findings of the only other relevant study by Zerguini and co-workers (2007). During the post-Ramadan period there was a considerable increase and recovery of $\dot{V}O_{2\max}$ values noted. These fluctuations in aerobic power are highly likely to be associated with the statistically significant changes in dehydration, as measured by pre-training urine osmolality. However, the large effect size difference between the means of the control data (pre-Ramadan and post-Ramadan) suggests that aerobic power during the post-Ramadan evaluation was still slightly below pre-Ramadan $\dot{V}O_{2\max}$ values. This observed reduction in estimated $\dot{V}O_{2\max}$ post-Ramadan, is again consistent with the findings of Zerguini and colleagues (2007), and may indicate a slight reversibility of training adaptations associated with aerobic power following Ramadan.

One possible detraining factor in aerobic power performance is possibly an inability to tolerate higher velocities, which is an important aspect of endurance performance and associated with habitual training volume and speed (Bassett and Howley, 2000; Jones and Carter, 2000). Running economy and tempo of play during training may be negatively affected by the degree of pre-training dehydration and considerable fluid loss during training (~2% body weight). Consequently post-Ramadan, during the higher absolute speeds that are involved in the progressive estimated $\dot{V}O_{2\max}$ test (Ramsbottom *et al.,* 1988), the players may not have been capable of sustaining the then less familiar higher velocities in the test, and this was reflected in the lower estimated $\dot{V}O_{2\max}$ test values during the post-Ramadan assessment.

The considerably greater pre-training dehydration state of the players during Ramadan also stimulated a classic elevation of heart rate to the standardised sub-maximal aerobic evaluation using YYIRT for 9 min (Krustrup *et al.,* 2003). The ramifications of a higher heart rate at an absolute intensity will ultimately lead to reduced training and performance capabilities as well as premature fatigue. Post-Ramadan there was a significant fall in the $\%HR_{max}$ recorded at the end of the "YYIRT 9 min", and this trend supports the findings of the authors Ramadan and Barac-Nieto (2000). The lower heart rates observed post-Ramadan were associated with a marked reduction in pre-training hydration state. Also it is possible that a classic training effect transpired post-Ramadan with slightly lower heart rate responses caused by several exposures to the same standardised exercise (YYIRT 9 min).

The large effect size differences surrounding Ramadan indicate a reduction of anaerobic capacity during Ramadan, which was subsequently restored post-Ramadan. Of note, two players failed to complete the LAST and terminated the test during the second 60-s time trial of the LAST. This drop-out rate indicates that such high-intensity anaerobic work was not very well tolerated in some intermittent fasting players, and may signify poor carbohydrate consumption and consequently low glycogen levels, in some Islamic players during Ramadan. Furthermore, the symptoms reported by the players who dropped out early when performing the LAST included dizziness, fatigue, nausea, symptoms that are associated with hypoglycemia (Shanks *et al.,* 1994).

Vertical power was found to improve significantly during and post-Ramadan, and was probably a product of slightly lighter body weights in association with similar power outputs (Reilly and Waterhouse, 2005). Also, plyometric activity was introduced to the soccer-training programme around the start of Ramadan, and these activities may have contributed to performance improvements (Diallo *et al.,* 2001) and maintenance post-Ramadan. There were no significant differences for horizontal power measurements, although results did display a trend towards improvements similar to vertical power. The only notable difference regarding speed and agility measurements was with the 10-m sprint between pre-Ramadan and post-Ramadan, with a decrease in time of 0.06 s.

However, this improvement in 10-m speed is likley to be connected with biological variation of performance (preparedness) (Zatsiorsky, 1995) or possibly training improvements associated with conditioning drills, than factors connected with Ramadan. Dehydration levels were found to have retun to normal at the time of the post-Ramadan assessments.

11.7 Limitations

A limitation of Study-1 and Study-2 was the natural reduction in subject participation within the respective studies. The P.E. students involved in this investigation were active team sports players (rugby and soccer); thus injury was one of the main reasons behind several participants' withdrawal from a single test session, particularly the subjects involved in rugby. Furthermore, a reduction in subject number was also apparent in the main focus of the thesis with regards the professional soccer-players of Al-Ahli; transference of soccer club, and current or recovery from injury were the main explanations for the subject reduction. Previous investigators (Thomas and Reilly, 1979; Casajus, 2001) have also noted the reduction of player numbers for data analysis involving professional soccer players.

The validity aspect of Study-1 was limited through opportunity to conduct a direct cross-validation of the LAST with an established anaerobic capacity test, because of the work commitments of the army personnel involved and limited time in the UK of the author. Furthermore, there are no criteria to demonstrate that a person has produced a maximal anaerobic effort. These limitations were addressed logically through a combination of ten applicable studies using established anaerobic capacity assessments on subjects of similar background and fitness level. Consequently, a more comprehensive understanding of maximal anaerobic effort was generated via peak blood lactate values produced; mean criteria were established at a peak blood lactate value of 14.7 $mmol.l^{-1}$ for acceptance of validity.

During Study-3, there was incomplete adherence to the wearing of the Actimeter watches by the players for the full duration of the study; this restricted circadian variation analysis to the manual sleep diaries. Consequently, it was not possible to quantify sleep latency and efficiency. Furthermore, the purpose of core temperature analysis was to observe body-heat production during the training session with the greatest load regarding duration and intensity, reflective of match play. However, there were constant last-minute changes to the training objectives, and only one simulated game (11 v 11, 2 x 25 min, full-pitch) from 8 weeks of data analysis was recorded.

A key factor in the change of training objectives was associated with the unpredictable and frustratingly common situation of weekly fixture alterations by the Qatari Football Association. Such circumstances make it very difficult for head-coaches to carry out their weekly training plan, and result in frequent rotation of training session aims. Also, data analysis was restricted to only the one day, as the intestinal pills that were employed to quantify core temperature were typically passed by the players from the body within 24-hours.

There were no suitable or available indoor facilities during this investigation, therefore during Study-4 the YYIRT (Krustrup *et al.,* 2003) was not applicable based on the findings of Study-2. The YYIRT is a typical test used by many contemporary soccer fitness coaches and sports scientist alike. The YYIRT involves a combination of energy systems and is a sensitive test capable of detecting differences in high-intensity intermittent running performance, in players who possess a similar $\dot{V}O_{2max}$ value.

There is a lack of research on Islamic soccer players during and after Ramadan. Consequently, the aims of this thesis were directed towards developing a greater understanding of current soccer practice and performance changes surrounding the holy month. These restrictions reflected the fact that an experimental research design was not applicable for this thesis. An action research model is a closer approximation to what was feasible. Within this research design, it is acceptable to monitor real-world interventions without necessarily controlling all the variables affecting the outcomes. A particular problem in this study was the poor adherence of the subjects to strict Muslim tenets with regards the sleep-wake cycle. This lack of compliance with total abstinence was implicit in the Ramadan model of Reilly and Waterhouse (2007) who allowed for variation in the degree of conformity to strict religious practices. The issue of strict adherence is a sensitive one, of which researchers in this subject should be aware.

11.8 Schematic model of disturbances during Ramadan

The Ramadan model has been suggested to be a hybrid of time-zone transition, nocturnal shift-work and ageing models (Reilly and Waterhouse, 2005). An extension and modifications to certain aspects of this model will be proposed, in an attempt to aid the understanding of disturbances to homeostasis that occur with Islamic professional soccer players in the Arabian Gulf during Ramadan. In the schematic model (Figure 29), the period of Ramadan is contrasted with a non-Ramadan reference period (immediately post-Ramadan). Nutritional, behavioural and biological factors are integrated and linked to the effects on soccer fitness components. This schematic representation is produced from the observations derived from the studies of Ramadan within this thesis as well as appropriate investigations. A textual summary of the workings of this model is produced on the following pages.

Figure 29. Schematic circadian model for Islamic professional soccer players.

Ramadan

Ramadan advances each solar year by around 10-11 days, as the religious festival is based around the lunar year, which consists of approximately 354 days. Therefore, it is possible that Ramadan can occur during different times of the year, in different climatic surroundings with various combinations of daylight and darkness hours.

During the first few days of the religious festival of Ramadan, the circadian pattern of eating and drinking is drastically altered and restricted to the hours of darkness. This reversal of nutritional consumption naturally lengthens the day. Players attempt to ingest sufficient quantities of food and drink during the limited hours of the night that is often accompanied by an increase in socialising with family and friends. Therefore, the phase delay of the initial days of Ramadan is akin to westward time zone travel and elongation of daily routine. The natural freewheel of circadian rhythms is around 25-27 hours (Reilly, 1987); consequently, there is a relatively quick adaptation to the Ramadan schedule, and so potential symptoms associated with a jet-lag type effect are less severe. Reduced amplitudes and 2-3 hour delays in acrophase of body temperature rhythms have been noted in sedentary Muslims during Ramadan (Roky *et al.*, 2004). Additionally, many Islamic societies adjust their soccer-training and match times to late evening (20:30 to 22:30 hours) to accommodate the intermittent fast.

As a result, the relatively greater catecholamine levels associated with night-time soccer activity would potentially inhibit melatonin secretion and affect the regulation of the body's biological clock (Tortora and Gabowski, 1996). The combination of the delay in acrophase of body temperature (Roky *et al.*, 2004) and increased catecholamine levels following soccer activity can result in problems with sleep latency (Reilly, 2003), and any attempt to maintain a normal bedtime routine during Ramadan was subjectively reported as pointless. As a result, many Islamic players delayed bedtime until after the first prayer of the day (04:05 to 04:20 hours), and the final meal before sunrise (suhur). Sleep duration is also considerably lengthened during Ramadan, possibly as an outcome of poor sleep efficiency during daylight hours. The upshot of a delay in bedtime until pre-sunrise is a substantial delay in wake-up time during the holy month.

The nutritional ritual of restricted food ingestion until darkness is affected by circadian rhythms of gut motility. Gastric emptying rate during the night is slower. Thus, Muslims ingesting a large meal during late evening or early morning are more likely to experience sensations of feeling bloated (Reilly and Waterhouse, 2007), and these feelings are likely to suppress the desire for further calorie consumption. The majority of evidence (Karaagaoglu *et al.,* 2000; Leiper and Molla, 2003) suggests a deficit of energy intake and balance occurs during Ramadan. The ramification of low carbohydrate consumption with regards crucial soccer activities and distance covered can be costly (Saltin, 1972). Pre-training dehydration of the players is another key outcome of fluid abstinence during daylight. Yet, the severity of dehydration can subside from week-1 to week-4 of Ramadan, associated with greater fluid intake during the night and greater fluid retention from renal adaptations (Sweileh *et al.,* 1992). Pre-exercise hypohydration can hinder potential performance of high-intensity endurance activity (Maughan and Shirreffs, 2004).

During Ramadan an interaction of sleep-wake-cycle disturbances, likely reduction of calorie consumption as well as energy reserves, and the effects of chronic dehydration influence the discrete components of soccer-fitness. Aerobic power is reduced, there is an increase in the $\%HR_{max}$ at a standardised sub-maximal intermittent aerobic task, anaerobic capacity tends to be reduced and tolerance of such work is notably less. For anaerobic power activities that are predominately dependent on the phosphocreatine energy system (horizontal-power, vertical-power, speed, and agility) performance is typically maintained and improvements have been noted associated with a reduced body-mass from dehydration and no change in power output (Reilly and Waterhouse, 2007).

Post-Ramadan

Immediately post-Ramadan, there is a reversal of the elongated sleep-wake cycle that occurs during Ramadan; in this case the re-synchronisation of circadian rhythms to a normal non-Ramadan daily routine is similar to the phenomenon of eastward time zone travel. The advancing sleep-wake cycle causes bedtime and wake-up time to be considerably earlier, and sleep duration is restored to the normal 8-9 hours for soccer players. However, the jet-lag type symptoms (headaches, digestive discomfort, reduced daytime alertness, lack of energy, disorientation, sleeping difficulties, general grogginess as well as loss of appetite) are more severe and longer lasting, causing readjustment to be slow (Reilly, 2003). It was not until around two weeks post-Ramadan that the sleep-wake cycle stabilized to a normal non-Ramadan level. Furthermore, the players may feel excessive daytime sleepiness, and some players increase the frequency of afternoon naps during this time, a common feature of the ageing circadian model.

Nutritional restraints are released following Ramadan and players can consume food and drink ad-libitum. Daytime gastric emptying rate is faster, so sensations of feeling bloated are likely to be less. Consequently, the potential for energy balance and carbohydrate intake is greater. However, the urine osmolality levels taken during the first week post-Ramadan were noted to be similar to those recorded during the final week of Ramadan and there was no significant interaction between Ramadan and non-Ramadan training weeks (n = 4). Thus, the urine osmolality values also highlight the slow readjustment to a non-Ramadan nutritional routine. Nevertheless, pre-training dehydration urine osmolality values are significantly less than Ramadan.

Two weeks post-Ramadan, the interaction of the re-synchronisation of the sleep-wake cycle to a non-Ramadan routine, the potential nutritional restoration of energy balance and the significant reduction in the degree of pre-training dehydration in players, affect the separate components of soccer fitness. The estimated $\dot{V}O_{2max}$ values are substantially improved towards pre-Ramadan baseline values; however, there is a possibility in many cases of a detraining effect in aerobic power. The $\%HR_{max}$ response to a standardised sub-maximal intermittent aerobic task is normalised, and associated with the return to euhydration.

Anaerobic capacity and tolerance to working at related high-intensities is restored, probably associated with energy balance and subsequent improvement in muscle glycogen content. Anaerobic power performances are generally maintained or in some circumstances improved, associated with training specificity employed surrounding Ramadan.

11.9 Practical Application

For the planning of a soccer-season for teams including Islamic players, it is essential to consider the holistic effects of lifestyle changes and consequences on training and performance during Ramadan. Periodisation provides the necessary structure for controlling stress and stimulating training improvements based around Hans Selye's general adaptation syndrome described by various authors (Zatsiorsky, 1995; Bompa, 1999; Siff, 2003). Training cycles usually follow a pattern of alternating various sequences of training overload and regeneration weeks in a 1:1; 2:1; 3:1; 4: 1 design (Smith, 2003). This thesis has employed the modified TRIMP method Brandon (2005) to quantify training load. Reducing training volume during a regeneration week by 60-90% has been found to improve subsequent performance (Shepley *et al.*, 1992; Houmard, *et al.*, 1994), but it is crucial that quality and intensity are maintained in some form (Smith, 2003).

Therefore, the weekly training cycle objectives surrounding Ramadan could be structured in a training-load and regeneration ratio of 1:1, 3:1 (Table XXVIII) to accommodate the additional lifestyle stress associated with Ramadan, and training.
The final week before the start of Ramadan could be planned as a high-load training week. Subsequently, the first week during Ramadan may then be scheduled as a regeneration week thereby, reducing training volume by as much as 60- 90% and maintaining some form of aerobic high-intensity activity. Consequently, not only is physiological stress from training during week-1 of Ramadan decreased and a favourable state for adaptation from the high-load week prior to Ramadan created, but also such a structure would also allow the Islamic player to cope better with the additional stress imposed from lifestyle changes of Ramadan, in particular the consequences of the start and adjustment to intermittent fasting. Simultaneously, hydration strategies should be introduced and dehydration evaluated daily through urine analysis pre-training and fluid loss post-training, with players ingesting 1.5 l of fluids for every 1 kg reduction in body weight to restore hydration status (Maughan and Shirreffs, 2004). As the weeks progress during Ramadan, training load can be increased; it is logical for the highest training load to be induced during for the final week of Ramadan (subject to the importance of games), when players have become more accustomed to the lifestyle changes and found a new nutritional equilibrium.

Immediately post-Ramadan another regeneration week could again be planned. Once more reducing stress from training, and facilitating adaptation to the previous week's high training load. Also, a regeneration week directly after Ramadan will help players cope with the additional lifestyle stress caused by the re-synchronisation of circadian rhythms to a normal non-Ramadan daily routine that are akin to eastward time zone travel. The symptoms associated with eastward time travel and advancement in the sleep-wake cycle is more severe and longer lasting, in contrast to a phase delay and westward time travel. In this investigation, sleep-wake cycles were found to take around two weeks to return to normal following Ramadan. Therefore, a low to moderate training load week during the second week following Ramadan would further facilitate Islamic soccer players to cope with the additional stress from the latter stages of re-synchronisation of circadian rhythms and the need to resume normal soccer practice.

Table XXIX: Recommended training cycle for Islamic soccer players surrounding Ramadan

Weeks surrounding Ramadan	Objective
Before and 1st week of Ramadan	
Week prior to Ramadan –	moderate/high training load
Week -1 Ramadan –	regeneration week
During Ramadan and 1st week post-Ramadan	
Week -2 Ramadan	low/moderate training load
Week -3 Ramadan	low/moderate/high training load
Week -4 Ramadan	low, moderate/high training load
Week -1 post-Ramadan	regeneration week
2nd week post-Ramadan	
Week -2 post-Ramadan	low/moderate training load

- Note: The objective of the training load week (low, moderate, high) will vary determined by team fixtures and importance of games.

- Week-2 post Ramadan – start of next training cycle with the training load: regeneration week ratio determined by importance of games and phase of the season.

11.10 Conclusion

The aim of this thesis was to investigate lifestyle changes, soccer training, and discrete soccer fitness components surrounding 4 weeks of intermittent fasting during the holy month of Ramadan. The aims have been fulfilled through a series of studies that firstly completed the comprehensive battery of soccer-specific fitness tests, through piloting an anaerobic capacity test for soccer players. Subsequently, the battery of soccer tests was evaluated for robustness and suitability for use in the adverse climate of Qatar. Workload during practice, circadian adjustments, environmental conditions, dehydration status of players, fluid loss, and core temperature during training were all observed in a qualitative study, in order to gain a greater insight into lifestyle changes and soccer training surrounding Ramadan. The soccer-specific battery of tests (n=15) was administered at four time points of the season surrounding Ramadan. The main conclusions from this investigation can be summarised as follows.

In relation to Study-1, the LAST was found to be reliable, valid, and a practical measure of anaerobic-capacity in a soccer-specific context requiring two familiarisation sessions. During Study-2, 15 out of 16 tests within the soccer specific battery of field tests were found to be appropriate for application in the heat; only the YYIRT (Krustrup *et al.,* 2003) to volitional exhaustion was found to be unsuitable.

With regards the lifestyle changes in Study-3 sleep disturbances within Ramadan significantly delayed bedtime, wake-up time and lengthened sleep duration. Post-Ramadan the re-synchronisation of circadian rhythms to a normal non-Ramadan daily routine was comparable to the occurrence of eastward time zone travel. Pre-training dehydration was considerably greater during Ramadan in contrast to non-Ramadan periods. Furthermore, during Ramadan there was a marked reduction in the degree of dehydration pre-training from week-1 to week-4. Fluid loss during Ramadan and non-Ramadan over the months of September and October for Qatari soccer players was considerable (>2% body mass). It is crucial that the additional stresses of circadian disturbances and nutritional abstinence during Ramadan are taken into consideration, and adjustments made within training

The aim of Study-4 was to investigate the changes in soccer-fitness components surrounding Ramadan. Aerobic power was significantly reduced, associated in part with pre-training dehydration. Post-Ramadan, this decrease in estimated $\dot{V}O_{2max}$ values was still below pre-Ramadan and scores, and large effect size calculations between non-Ramadan periods suggest a possible detraining effect. There was a classic elevation of heart rate in sub-maximal exercise with a standardised test YYIRT 9 min (Krustrup *et al.,* 2003) associated with pre-training dehydration, post-Ramadan this increase was reversed in line with a significant reduction in pre-training dehydration. High-intensity anaerobic work was not tolerated very well, and a moderate reduction in effect size of anaerobic capacity was observed, possibly linked with a negative calorie balance. Some power activities (vertical jump) were improved during Ramadan, likely connected with lighter body weight and maintenance of power output. For speed and agility performance, no changes were observed related to the effects of Ramadan.

11.11 Future recommendations

11.11.1 Night-time rehydration strategies during Ramadan

The key findings from studies 3 and 4 highlight the detrimental consequences of acute and chronic dehydration on training as well as performance measurements. Therefore of interest and practical use, would be an investigation on the effects of various fluid interventions before, during, and after training and games within Ramadan.

As a product of the high-intensity demands of soccer training and games sweat loss will occur, often leading to a degree of dehydration which impairs exercise capabilities (Maughan and Leiper, 1994). Moreover, a significant deterioration of skill performance has also been associated with dehydration and high-intensity soccer activity (McGregor *et al.,* 1999). Therefore, the application of rehydration strategies before as well as during training and games would be prudent, especially with Islamic players who are adhering to the intermittent fast of Ramadan and are training or playing during the evening. Fluid consumption during soccer activity will provide water to reduce the negative effects of dehydration and provide additional carbohydrates to supplement the body's limited glycogen stores. Hypotonic carbohydrate-electrolyte beverages are the most suitable for hot climates during activity, since the absorption rate from the stomach is much faster in contrast to isotonic or hypertonic drinks (Maughan and Leiper, 1994). Furthermore, fluid breaks should be formally integrated with coaching points and/or changes of soccer drill within a training session in contrast to sporadic fluid consumption determined by the players.

Following evening training sessions and soccer matches during the Ramadan festival, it is essential to ensure rehydration strategies are employed to assist the recovery process and facilitate the player to start subsequent training days and matches in a euhydrated state (Maughan *et al.,* 1997). The amount of fluid loss of soccer players has been found to have a large individual variability and accordingly individualized analysis of hydration status of players should be used to optimise fluid strategies of players (Maughan *et al.,* 2007).

It has been suggested (Reilly and Ekblom, 2005) that the sole use of water is not the best way to replenish body fluids. Ingestion of large amounts of plain water will hamper thirst as well as promoting a diuretic response (Maughan *et al.,* 1997). Moreover in comparison to water, carbohydrate-electrolyte beverages provide superior intestinal absorption as well as reducing urine production. Furthermore, protein supplementation added to carbohydrate beverages can further enhance glycogen resynthesis (Berardi *et al.,* 2006). The consumption of isotonic or hypertonic carbohydrate-electrolyte drinks should commence immediately post-training session or game and provides an ideal means of consuming additional carbohydrates for soccer players (Reilly and Ekblom, 2005). To overcome ongoing necessary urine and sweat losses post-exercise, the volume of fluids consumed should be greater than the volume of sweat lost during soccer activity. It has been recommended that for every 1 kg lost of body fluids during exercise approximately 1.5l of fluids be required to ensure adequate volume replacement. Additionally, palatability is also a key factor in ensuring sufficient fluid intake (Maughan *et al.,* 1997). Finally, beverages containing caffeine should also be considered within any night-time rehydration strategies during Ramadan, since it is a potent physhoactive substance which has a profound influence on sleep and wake function (Roehrs and Roth, 2007). Therefore, such beverages may be best avoided in the hours before desired sleep.

Negative energy balance within some Muslims has been widely observed during Ramadan. Therefore nutritional consumption during intermittent fasting in combination with estimated calorie expenditure during soccer training would be beneficial, and provide the foundations for advice on nutritional supplementation. Dietary analysis should include the iron content within the players' daily consumption, as reductions in serum iron have been noted within the literature and "sports pseudo anaemia" may also contribute to sub-optimal performance. Furthermore, during Study-4, two players reported symptoms indicative of hypoglycaemia; thus, the timing, glycaemic index type, and quantity of carbohydrate ingestion pre-training appear to be other important nutritional aspects surrounding Islamic soccer players during Ramadan that are worthy of further investigation.

11.11.2 Performance

Notational analysis during games before and immediately after Ramadan would establish the effects of current practice on physical performance of match-play with particular focus on high-intensity activity. Subsequently, the effects of any nutritional intervention strategy could be assessed in both discrete soccer fitness components via testing as well as match-performance.

The detraining effects in aerobic power noted post-Ramadan in this investigation support the findings of other relevant work. Therefore, it would be of practical assistance to coaches, for investigations into various training interventions to address potential reversibility of the training in aerobic power.

11.11.3 Lifestyle body clock

This thesis has focused on lifestyle changes associated with Islamic professional players working in a Muslim country whereby, working conditions and society are modified around the religious festival of Ramadan. It is still not clear how the lifestyle changes in circadian rhythms will influence those Islamic players who play soccer and live in non-Muslim societies, training and playing during daylight hours with and against non-fasting soccer players. Therefore, further investigations on Islamic players are warranted with regards the various degrees of adherence to strict religious practice during Ramadan. These research proposals have practical relevance for professional coaches and sports science support staff working in the United Kingdom with professional soccer clubs.

References

Afifi, Z.E. (1997). Daily practices, study performance and health during the Ramadan Fast. *Journal of Research in Sociology and Health*, **117**, 231-235.

Agnevik, G. (1970). Football. A Report in Sports Physiology. Stockholm: Trygg-Hansa.

Al-Hazzaa H.M., Almuzani, K.S., Al-Refaee, S.A., Sulaiman, M.A., Dafterdar, M.Y., Al-Ghamedi, A. and Al-Khuraiji, K.N. (2001). Aerobic and anaerobic power characteristics of Saudi elite soccer players. *Journal of Sports Medicine and Physical Fitness*, **41**, 54-61.

Ali, M.R. and Amir, T. (1989). Effects on fasting on visual flicker fusion. *Perceptual and Motor Skills*, **69**, 627-631.

Anderson, O. (2000). New vVO_2 max sessions lead to impressive gains in fitness. *Peak Performance*, **142**, 3-6.

Andersen, L.B. (1994). Changes in physical activity are reflected in changes in fitness during late adolescence. A 2-year follow-up study. *Journal of Sports Medicine and Physical Fitness*. **34**, 390-397.

Angel, J.F. and Schwartz, N.E. (1975). Metabolic changes resulting from decrease meal frequency in adult males Muslims during the Ramadan fast. *Nutritional Report International*, **11**, 29-38.

Apor, P. (1988) Successful formulae for fitness training. In *Science and Football* (edited by T. Reilly, A. Lees, K. Davids, and W.J. Murphy), pp. 95-107. London: E & FN Spon.

Armstrong, L.E. and Maresh, C.M. (1991). The induction and decay of heat acclimatization in trained athletes, *Sports Medicine*, **12**, 302-12.

Aroso, J., Rebelo, A.N. and Gomes-Piereina, J. (2004). Physical impact of selected game related activities. *Journal of Sports Sciences*, **22**, 522.

Asakawa, I, A., Bowers, C.Y., Mantovani, G., Laviano, A., Mequid, M.M. and Fujimiya, M. (2004). Ghrelin, appetite, and gastric motility: the emerging role of the stomach as an endocrine organ. *Federation of American Societies for Experimental Biology*, **18**, 439-456.

Astrand, P.O. and Rodahl, K. (2003). *Textbook of Work Physiology*. New York: McGraw-Hill.

Atkinson, G. and Nevill, A.M. (1998). Statistical methods for assessing measurable error (reliability) in variables relevant to sports medicine, *Sports Medicine*, **26**, 217-238.

Atkinson, G. and Nevill, A.M. (2001). Selected issues in the design and analysis of sport performance research. *Journal of Sports Sciences,* **19**, 811-827.

Aziz, A.R. and Tan, F.H.Y. (2005). A pilot study comparing two field tests with the treadmill run in soccer players. *Journal of Sports Sciences and Medicine,* **4**, 105-112.

Baechle, T. (1994). *The Essentials of Strength Training and Conditioning: National strength and Conditioning Association.* Champaign, IL: Human Kinetics.

Baechle, T.R. and Earle, R.W. (2000). *Essentials of Strength Training and Conditioning. National Strength and Conditioning Association.* Champaign, IL: Human Kinetics.

Bahammam, A. (2005). Assessments of sleep patterns, daytime sleepiness, and chronotype during Ramadan in fasting and non-fasting individuals. *Saudi Medical Journal,* **26**, 616-622.

Bale., P., Mayhew, J.L., Piper, F.C., Ball. T.E. and Willman, M.K. (1992). Biological and perofrmance variables in relation to age, height, and body mass on motor performance during adolescence (13-18 years). *Journal of Sports Medicine and Physical Fitness,* **32**, 142-148.

Balsom, P., Seger, J.Y., Sjodin, B. and Ekblom, B. (1992b). Maximal-intensity intermittent exercise: effect of recovery duration. *International Journal of Sports Medicine,* **13**, 528-533.

Balsom, P.D. (1988). The relationship between aerobic capacity, anaerobic power, anaerobic capacity, anaerobic threshold, and performance decrementation in male colligate soccer players. *Springfield College,* Springfield, MA.

Balsom, P.D. (1990). A field test to evaluate physical performance. In *Football (soccer)* (edited by B.Ekblom), pp. 102-123. London: Blackwell.

Balsom, P.D., Gaitanos, G.C., Soderlund, K. and Ekblon, K. (1999). High intensity exercise and muscle glycogen availability in humans. *Acta Physiologica Scandinavica,* **165**, 337-345.

Balsom, P.D., Seger, J.Y., Sjodin, B. and Ekblom, B. (1992a). Physiological responses to maximal intermittent exercise. *European Journal of Applied Physiology,* **65**, 144-149.

Bangsbo, J (1994). *Fitness Training in Football, - A Scientific approach.* Baegsvard: H + O Storm.

Bangsbo, J. (1992). Time motion Characteristics of competition soccer. In *Science and Football II* (edited by T. Reilly, J. Clarys, and A. Stibble), London: E. and F.N. Spon.

Bangsbo, J. (1994). Energy demands in competitive soccer. *Journal of Sports Sciences*, **12**, S5-12.

Bangsbo, J. (1996). *YO-YO tests*. Copenhagen, Denmark: HO + Strom.

Bangsbo, J. (1998). Quantification of anaerobic energy production during intense exercise. *Medicine and Science in Sport and Exercise*, **30**, 47-52.

Bangsbo, J. (2003). *Fitness Training in Soccer. A Scientific Approach*. Auburn, Michigan: Reedswain Publishing.

Bangsbo, J. and Lindquist, F. (1992). Comparisons of various exercise tests with endurance performance during soccer in professional players. *International Journal of Sports Medicine*, **13**, 125-132.

Bangsbo, J. (2003). In *Science and Soccer (2nd Edition)* (edited by T.Reilly, and M.A. Williams), pp 47-58. London: Routledge.

Bangsbo, J., Mohr, M. and Krustrup, P. (2006). Physical and metabolic demands of training and match play in the elite football player. *Journal of Sports Sciences*, **24**, **7**, 665-674.

Bangsbo, J., Norregaard, L. and Throrsoe, F. (1991). Activity profile of competition soccer. *Canadian Journal of Sport Sciences*. **16**, 110-116.

Bar-Or, O. (1987). The Wingate anaerobic test: an update on the methodology, reliability, and validity. *Sports Medicine*, **4**, 381.

Bassett, D.R. and Howley, E.T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine and Science in Sports and Exercise*, **32**, 70-84.

Bassett, D.R. and Howley, E.T. (1997). Maximal oxygen uptake: "classical" versus "contemporary" viewpoints. *Medicine and Science in Sports and Exercise*, 29, 591-603.

Baquet, G., Twisk, J.W., Kemper, H.C., Van Praagh, E. and Berthoin, S. (2006) Longitudinal follow-up of fitness during childhood: interaction with physical activity. *American Journal of Human Biology*, **18**, 51-58.

Beunen, G., Ostyn, M., Simons, J., Renson, R., Claessens, A.L., Vanden Eynde, B., Lefevre, J., Vanreusel, N., Malina, R.M. and Van't Hof, M.A. (1997). Development and tracking in fitness components: Leuven longitudinal study on lifestyle, fitness and health. *International Journal of Sports Medicine*, 18, (3), 171-178.

Berardi, J.M., Price, T.B., Noreen, E.E. and Lemon, P.W, (2006). Post-exercise muscle glycogen recovery enhanced with a carbohydrate-protein supplement. *Medicine and Science in Sports and Exercise*, **38**, 1106-1113.

Billat, L.V. and Koralsztein, J.P. (1996). Significance of the velocity at VO_2 max and time to exhaustion at this velocity. *Sports Medicine*, **22**, 90-108.

Billat, V., Flechet, B., Petit, B., Muriaux, G. and Koralsztein, J.P. (1999). Interval training at VO_{2max}- effects on aerobic performance and overtraining markers. *Medicine and Science in Sports and Exercise*, **31**, 156-163.

Billows, D., Reilly, T. and George, K. (2003). Physiological demands of matchplay on elite adolescent footballers. Communication: *World Congress of Science and Football-5*, 159.

Bloomfield, J., Polman, R. and O'Donoghue, P. (2007). Turning movements performed during FA Premier League soccer matches. *Journal of Sports Science and Medicine*, **10**, 9.

Bogdan, A., Bouchareb, B. and Touitou, Y. (2005). Response of circulating leptin to Ramadan daytime fasting: a circadian study. *British Journal of Nutrition*, **93**, 515-518.

Bompa, T.O. (1999). *Periodisation: Theory and Methodology of Training* (4th ed.). pp 358. Toronto, ON: Human Kinetics.

Bompa, T.O. and Cornacchia, L.J. (1998), *Serious Strength Training*. Champaign, IL: Human Kinetics.

Bondarchuk, A. (2003). In *SUPERTRAINING (6^{th} Edition)* (edited by M. Siff). Denver, USA: Supertraining Institute.

Boobis, L.H. (1987). *Metabolic aspects of fatigue during sprinting*. In *Exercise and Benefits, Limits and Adaptations* (edited by D. Macleod, R. Maughan, M. Nimmo, T. Reilly and C. Williams), pp 116-143. London: E & F.N. Spon.

Borenstein, M., Rothstein, H. and Cohen, J. (1997). *Power and Precision*, Biostat, Teaneck, NJ, Software for MS-DOS systems.

Bosco, C. (1990). Strength elasticity in football. In *Sports Medicine Applied to Football* (edited by G. Santilli), pp 63-70 Rome: CONI.

Bosco, C.P., Luhtanen, P. and Komi, P.V. (1983). A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology,* **50**, 273-282.

Bouchard, C., Taylor, A.W., Simoneau, J.A. and Dulac, S. (1991) Testing anaerobic power and capacity. In *Physiological Testing of High Performance Athlete* (edited by J.D. McDougall, H.A. Wenger and H.J. Green), pp 175-221.Champaign, IL: Human Kinetics.

Brandon, R. (2005). Training schedules: Three ways to quantify and evaluate your training and make sure you are achieving what your coach has planned for you, *Peak Performance,* July. Online: http://www.pponline.co.uk/encyc/training-schedules.html.

Broad, E. N., Burke, L.M. and Cox, G.R. (1996). Body weight changes and voluntary fluid intakes during training and competition sessions in team sports. *International Journal of Sports Nutrition,* **6**, 307-320.

Brooks, G.A., Fahey, T.D. and White, T.P. (1995). *Exercise Physiology. Human Bioenergetics and its Applications* (2nd Edition). California: Mayfield Publishing Company.

Burden, M. (2001). Culturally sensitive care: managing diabetes during Ramadan. *British Journal of Community Nursing,* **6**, 581-585.

Burke, L.M., Loucks, A.B. and Broad, N. (2006). Energy and carbohydrate for training and recovery. *Journal of Sports Sciences,* **24**, 675-685.

Buskirk, E.R., Iampietro, P.F. and Bass, D.E, (1958). Work performance after dehydration: effects of physical conditioning and heat acclimatisation. *Journal of Applied Physiology,* **12**, 189-194.

Buttifant, D. and Graham, K. (1999) Agility and speed measurement in soccer players are two different performance parameters. In *Book of Abstracts 4th World Congress of Science and Football,* pp 57. Sydney, Australia.

Buttifant, D., Graham, K. and Cross, K. (2002). Agility and Speed in soccer players are two different performance parameters. In *Science and Football IV* (edited by W. Spinks, T. Reilly and A. Murphy), pp.329-332. London: Routledge.

Cadarette, B.S., Sawka, M. N., Toner, M.M. and Pandolf, K.B. (1984). Aerobic fitness and the hypohydration response to exercise heat-stress. *Aviat Space Environment Medicine,* **55**, 507-512.

Carsten, J., Klarskov, C., Nielsen, J.J., Krustrup, P., Mohr, M. and Bangsbo, J. (2004). Effect of high intensity intermittent training on lactate and H^+ release from human skeletal muscle. *American Journal of Physiology Endocrinology and Metabolism,* **286,** E245-E251

Casa, D.J., Armstrong, L.E., Hillman, S.K., Montain, S.J., and Reiff, R.V., Rich, B.S.E., Roberts, W.O. and Stone, J.A. (2000). National athletic training association position statement: Fluid replacement for athletes. *Journal of Athletic Training,* **35,** 212-224

Casajus, J.A. (2001). Seasonal variation in fitness variables in professional soccer players. *Journal of Sports Medicine and Physical Fitness,* **41,** 262-266.

Castagna, C., Abt, G. and D'Ottavio, S. (2005). Competitive level differences in Yo-Yo intermittent Recovery and 12 minute run performance in soccer referees. *Journal of Strength and conditioning Research,* **19,** 805-809.

Castagna, C., Impellizzeri, F.M., Chamari, K., Carlomagno, D. and Rampini, E. (2006). Aerobic fitness and Yo-Yo continuous and intermittent test performances in soccer players: A correlation study. *Journal of Strength and Conditioning Research,* **20,** 320-325.

Chamari, K., Hachana, Y., Ahmed, Y.B., Galy, O., Sghaier, F.,Chatard, J.C., Hue, O. and Wisloff, U. (2003). Field and Laboratory testing in young elite soccer players. *British Journal of Sports Medicine,* **38,** 191-196.

Chamari, K., Hachana, Y., Kaouech, F., Jeddi, R., Moussa-Chamari, L. and Wislof, U. (2005). Endurance training and testing with the ball in young elite soccer players. *British Journal of Sports Medicine,* **39,** 24-28.

Cheetham, M.E., Williams, C. and Lakomy, H.K. (1985). A laboratory running test: metabolic responses of sprint and endurance trained athletes. *British Journal of Sports Medicine,* **19,** 81-84.

Cheng, B., Kuipers, H., Snyder, A.C., Keizer, H.A., Jeukendrup, A. and Hesselink, M. (1992). A new approach for the determination of ventilatory and lactate thresholds. *International Journal of Sports Medicine,* **13,** 518-522.

Considine, R.V., Sinha, M.K., Heiman, M.L., Kriauciunas, A., Stephans, T.W., Nyce, M.R., Ohannesian, J.P., Marco, C.C., McKee, L.J. and Bauer, T.L. (1996). Serum immunoreactive-leptin concentrations in normal weight and obese humans. *The New England Journal of Medicine,* **334,** 292-295.

Coris, E., Ramirez, E.A.M. and Van Durme, D.J. (2004). Heat illness in athletes, the dangerous combination of heat humidity and exercise. *Sports Medicine,* **34,** 9-16.

Coyle, E.F., Coggan, A.R., Hopper, M.R. and Waters, T.J. (1988). Determinants of endurance in well-trained cyclists. *Journal of Applied Physiology*, **64**, 2622-2630.

Da Silva, S.G., Kaiss, W., Campos, W. and Ladewig, I. (1999). Decrease in aerobic power and "anaerobic threshold" variables with age in Brazilian soccer players. *Journal of Sports Sciences*, **17**, 823.

Datson, N., Drust, B., Atkinson, G. and Gregson, W. (2007). Effects of pre-cooling and warm-up intensity on soccer specific intermittent exercise performance in heat. *Journal of Sports Sciences*, **10**, 184-185.

Davis, J.A. and Brewer, J. (1992). Physiological characteristics of an international female soccer squad. *Journal of Sports Sciences*.**10**, 142-143.

Dawson, B. (2003). Speed, agility and football. In *Book of Abstracts, 5th World Congress of Science and Football.* (edited by F. Alves, J. Cabri, J.A. Diniz, and T.Reilly), pp.14. Lisbon, Portugal: Editorial Gymnos.

DeMello, J.J., Snow, S., Bellew, J. and Winter, T. (2003). Aerobic and anaerobic abilities of state level Olympic development soccer players. In *Book of Abstracts, 5th World Congress of Science and Football.* (edited by F. Alves, J. Cabri, J.A. Diniz, and T.Reilly), pp. 183. Lisbon, Portugal: Editorial Gymnos.

Di Salvo, V., Baron, R. and Cardinale, M. (2007). Time motion analysis of elite footballers in European cup Competitions. *Journal of Sports Science and Medicine*, **10**, 14.

Diallo, O., Dore, E., Duche, P. and Praagh, E. (2001). Effects of plyometric training followed by a reduced training programme on physical performance in prepubescent soccer players. *Journal of Sports Medicine and Physical Fitness*, **41**, 342-8.

Doha Qatar Weather: Online: http://www.wunderground.com/global/stations/41170.html.

Dourado, A.C., Reeberg Stanganelli, L.C., Daros, L.B., Frisselli, A., Montanholi, A.F. and Osieck, R. (2007). Assessment of anthropometric characteristics and sprint velocity in soccer players from 5 different groups. *Journal of Sports Science and Medicine*, **10**, 136-137.

Draper, J.A. and Lancaster, M.G. (1985). The 505 test: A test for agility in the horizontal plane. *Australian Journal of Science and Medicine*, **17**, 15-18.

Dunbar, J. and Treasure, D. (2003). An Analysis of fitness profiles as a function of playing position and playing level in three English premier league soccer clubs. In *Book of Abstracts, 5th World Congress of Science and Football.* (edited by F. Alves, J. Cabri, J.A. Diniz, and T.Reilly), pp.186. Lisbon, Portugal: Editorial Gymnos.

Dupont, G.K.A. and Berthoin, S. (2004). The effect of in-season, high intensity interval training in soccer players. *Journal of Strength and Conditioning Research,* **18**, 584-589.

Durnin, J.V.G.A. and Womersley, J. (1974). Body fat assessed from total density and its estimation from skinfold thickness: measurement on 381 men and women aged 16-72 years. *British Journal of Nutrition,* **32**, 77-92.

Edwards, A.M. and Clark, N. (2003). A soccer specific fitness test differentiates between 1st team professional soccer players and Academy trainees. In *Book of Abstracts, 5th World Congress of Science and Football.* (edited by F. Alves, J. Cabri, J.A. Diniz, and T.Reilly), pp.189-190. Lisbon, Portugal: Editorial Gymnos.

Edwards, B., Watehrrhouse, J., Reilly, T. and Atkinson, G. (2002). A comparison of the suitabilities of rectal, gut, and insulated axilla temperatures for measurement of the circadian rythmn of core temperature in field studies
Chronobiology International, 2002, 19, 579.

Ekblom, B. (1986). Applied physiology of soccer. *Sports Medicine,* **3**, 50-60.

Ekblom, B. (1994). *Football. (Soccer).* Oxford: Blackwell Scientific Publications.

El-Ati, J., Beji, C. and Danguir, J. (1995). Increased fat oxidation during Ramadan fasting in healthily women: an adaptive mechanism for body weight maintenance. *American Journal of Clinical Nutrition,* **62**, 302-307.

Erith, S.J. (2004). An overview of fitness testing within English premier league football clubs. *Journal of Sports Sciences,* **22**, 247.

Esposito, F., Impellizzeri, F.M., Margonato, V., Vanni, R., Pizzini, G. and Veicsteinas, A. (2004). Validity of heart rate as an indicator of aerobic demand during soccer activities in amateur players. *European Journal of Applied Physiology,* **93**, 167-72.

Evans, A.D.B. and Reilly, T. (1980) The relation between performance in a throwing task and work-induced activation. *Ergonomics,* **23**, 1147-1149.

Fadail, S.S., Murphy, D.S. and Salih, D.S. (1982). Changes in certain blood constraints during Ramadan. *American Journal of Clinical Nutrition,* **36**, 350-354.

Faina, M., Gallozzi, C., Luppo, S., Colli, R., Sassi, R. and Marini, C. (1988). Definition of the physiological profile of the soccer player. In *Science and Football* (edited by T. Reilly, A. Lees, K.S. David, and W.J. Murphy). Pp 158-163. London: E and F Spon.

Fazel, M. (1998). Medical implications of controlled fasting. *Journal of the Royal Society of Medicine,* **91**, 260-262.

Finn, J.P., Wood, R.J. and Massden, J.F. (2003). Effects of 30°C Heat on the anaerobic capacity of heat acclimatized athletes. *Journal of Sports Science and Medicine,* **2,** 158-162.

Fitts, R. H. (1994). Cellular mechanisms of muscle fatigue. *Physiological Review,* **74,** 49 – 94.

Flanagan, T. and Merrick, E. (1999). Quantifying the work-load of soccer players. In *Science and Football IV* (edited by W. Spinks, T. Reilly, and A. Murphy), pp 341-349. London: Routledge.

Foran, B. (2001). *High-Performance Sports Conditioning.* Champaign, IL: Human Kinetics.

Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P. and Dodge, C. (2001). A new approach to monitoring Exercise Training. *Journal of Strength and Conditioning Research,* 15, 1, 109-115.

Fry, R.W., Morton, A.R. and Keast, D. (1992). Periodisation and the prevention of overtraining, *Canadian Journal of Sports Sciences,* **17,** 241-8.

Gastin, P.B. (2001). Energy system interaction and relative contribution during maximal exercise. *Sports Medicine,* **31,** 725-741.

Gauffin, H., Ekstrand, J., Arnesson, L. and Tropp, H. (1989). Vertical Jump performance in soccer players. *Journal of Human Movement Studies,* **16,** 215-224.

Gibson, C., Broomhead, S., Lqmbert, M.I. and Hawley, J.A. (1998). Prediction of maximal oxygen uptake from a 20-m shuttle run as measured directly in runners and squash players. *Journal of Sports Sciences,* **16,** 331-335.

Girden, E.R. (1992). *ANOVA: Repeated Measures.* Newbury Park: Sage.

Gollnick, P.D., Bayly, W.M. and Hodgson, D.R. (1986). Exercise intensity, training diet and lactate concentration in muscle and blood. *Medicine and Science in Sports and Exercise,* **18,** 334-340.

Gore, C.J. (2000). *Physiological tests for elite athletes.* pp 47, Chapter 3. Champaign, IL: Human Kinetics.

Green, H., Halestrap, A., Mockett, C., O'Toole, D., Grant, S. and Ouyang, J. (2002). Increases in muscle MCT are associated with reductions in muscle lactate after a single exercise session in humans. *American Journal of Physiology Endocrinology and Metabolism,* **282,** E154-E160.

Green, H.J. and Houston, M.E. (1975). Effect of a season of ice hockey on energy capacities and associated functions. *Medicine in Science and Exercise,* **7,** 299-303.

Green, S. (1992). Anthropometric and physiological characteristics of South Australian soccer players. *Australian Journal of Science and Medicine in Sport.* **24**, 3-7.

Hakkou, F., Wast, D. and Jaouen, C. (1988). Does Ramadan impair vigilance and memory. *Psychopharmacology,* **96**, 213.

Hakkou, F., Tazi, A., Iraqui, L., Celice-Pingaud, C. and Vatier, J. (1994). The observance of Ramadan and its repercussion on gastric secretion. *Gastroenterologie Clinique et Biologique,* **18**, 190-194.

Hallak, M.H. and Nomani, M.Z. (1988). Body weight loss and changes in blood lipid level in normal men on hypocaloric diets during Ramadan fasting. *American Journal of Clinical Nutrition,* **48**, 1197-1210.

Hawkins, R.D., Hulse, M.A., Wilkinson, C., Hodson, A. and Gibson, M. (2001). The association football medical research programme: an audit of injuries in professional football. *British Journal of Sports Medcine,* **35**, 43-7.

Hermansen, L. (1981). Effect of metabolic changes on force generation in skeletal muscle during exercise. *Ciba Found Symp,* **82**, 75-88.

Helgerud, J., Engen, L.C., Wisloff, U. and Hoff, J. (2001). Aerobic endurance training improves soccer performance. *Medicine and Science in Sports and Exercise,* **33**, 1925-1931.

Hodson, A., Thomas, A., Hawkins, R., Hulse, M., Simmons, C. and Ramsey, C. (2000). The F.A. Fitness Trainers Award-Pre-Course Learning. (Part-1). The Football Association Medical education Centre Lilleshall Hall National Sports Centre, Newport, Shropshire.

Hoff, J. and Helgeurd, J. (2004). Endurance and strength training for soccer players: Physiological considerations. *Sports Medicine,* **34**, 165-180.

Hoff, J., Wisløff, U., Engen, L.C., Kemi, O.J. and Helgerud, J. (2002). Soccer specific aerobic endurance training. *British Journal of Sports Medicine,* **36**, 218-221.

Hoffman, J.R. and Kaminsky, M. (2000). Use of performance testing for monitoring overtraining in elite youth basketball players. *Strength ad Conditioning Journal,* **22**, 54-62.

Hopkins, W.G., Hawley, J.A. and Burke, L.M. (1999). Design and analysis of research on sports performance enhancement. *Medicine and Science in Sports and Exercise,* **31**, 472-485.

Houmard, J.A. and Johns, R.A. (1994). Effects of taper on swim performance: practical implications. *Sports Medicine,* **17,** 224-232.

Houmard, J.A., Hortobagy, T. and Johns, R.A. (1992). Effect of short term training cessation on performance measures in distance runners. *International Journal of Sports Medicine,* **13,** 572-577.

Houmard, J.A., Kirwan, J.P. and Flynn, M.G. (1989). Effects of reduced training on submaximal and maximal running responses. *International Journal of Sports Medicine,* **10,** 30-33.

Housten, M.E., Bentzen, H. and Larsen, H. (1979). Training interrelationships between skeletal muscle adaptations and performance as study by detraining and retraining. *Acta Physiologica Scandinavica,* **102,** 163-170.

Howley, E.T., Basset. D.R. and Welch, H.G. (1995). Criteria for maximum oxygen uptake: Review and Commentary. *Medicine and Science in Sports and Exercise,* **27,** 1292-1301.

Hultman, E., Spriet, L.L. and Soderland, K. (1986). Biochemistry of muscle fatigue. *Biomed Biochem Acta,* **45,** S97-S106.

Husain, R, Duncan, M.T., Cheah, S.H. and Ch'ng, S.L. (1987). Effects of fasting Ramadan on tropical Asiatic Moslems. *British Journal of Nutrition,* **58,** 41-48.

Hughson, R.L., Weisiger, K.H. and Swanson, G.D. (1987). Blood lactate concentration increases as a continuous function of progressive exercise. *Journal of Applied Physiology,* **62,** 1975-1981.

Impellizzeri, F.M., Rampinini, E., Coutts, A.J., Sassi, A. and Marcora, S.M. (2004). Use of RPE-based training load in soccer. *Medicine and Science in Sports and Exercise,* **36,** 1042-1047.

Iraki, L., Bogdan, A., Hakkou, F., Amrani, N., Abkari, A. and Touitou, Y. (1997). Ramadan diet restriction modify the circadian time structure in humans. Study on plasma gastrin, insulin, glucose, and calcium, and on gastric pH. *Journal of Clinical Endocrinology Metabolism,* **82,** 1261-1273.

Jones, A.M. and Carter, H. (2000). The effect of endurance training on parameters of aerobic fitness, *Sports Medicine,* **29,** 373-386.

Karaagaoglu, N. and Yucecan, S. (2000). Some behavioural changes observed among fasting subjects, their nutritional habits and energy expenditure in Ramadan. *International Journal of Food Science and Nutrition,* **51,** 125-34.

Karlsson, J. (1971). Muscle metabolites during sub-maximal and maximal exercise in man. *Scandinavian Journal of Clinical investigation,* **26,** 382.

Kassab, S.E., Abdul-Ghaffar, T., Nagalla, D.S., Sachdeva, U. and Nayar, U. (2003). Serum leptin and insulin levels during chronic fasting. *Asia Pacific Journal of Clinical Nutrition,* **12,**483-487.

Kay, D., Taaffe, D.R. and Marino, F.E. (1999). Whole body pre-cooling and heat storage during self paced cycling performance in warm humid conditions. *Journal of Sports Sciences,* **17,** 937-944.

Kemi, O.J., Hoff, J., Engen, C., Helgerud, J. and Wisloff, U. (2003). Soccer specific testing of maximal oxygen uptake. *Journal of Sports Medicine and Physical Fitness,* **43,** 139-144.

Kenefick, R.W., Mahood, N.V., Mattern, C.O., Kertzer, R. and Quinn, T.J. (2002). Hypohydration adversely affects lactate threshold in endurance athletes. *The Journal of Strength and Conditioning,* **16,** 38-42.

Keneflick, R.W., Mattern, C.O., Mahood, N.V. and Quinn, T.J.(2002). Physiological variables at lactate threshold under-representing cycling time-trial intensity. *Journal of Sports Medicine and Physical Fitness,* **42,** 396-402.

Kentta, G. and Hassmen, P. (1998). Overtraining and recovery. A conceptual model. *Sports Medicine,* **1,** 1-16.

Kirkendale, D.T. (1993). Effects of nutrition on performance in soccer. *Medicine and Science in Sports and Exercise,* **25,** 1370-1374.

Klassen, K.L., Anderson, L.B. and Pelle, I. (1981). Adaptation changes in work capacity skeletal muscle, capillarization, and enzyme levels during training and detraining. *Acta Physiologica Scandinavica,* **113,** 9-16.

Kollath, F. and Quade., K.(1993). Measurement of sprinting speed of professional and amateur soccer players. In *Science and Soccer II* (edited by T.Reilly, J.Clarys and A.Stibble), pp. 31-36. London: E & FN Spon.

Komi, P.V. (1992). *Strength and Power in Sport (edited by Komi, P.V.): The Encyclopaedia of Sports Medicine An IOC Medical commission Publication in Collaboration with the International Federation of Sports Medicine.* p.61. Oxford, England: Blackwell Science.

Koutedakis, Y. (1995). Seasonal variation in fitness parameters in competitive athletes. *Sports Medicine,* **19,** 373-392.

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J. and Steensbergy, A. (2003). The Yo-Yo intermittent recovery test: Physiological Response, reliability and validity. *Medicine and Science in Sports and Exercise,* **35**, 695-705.

Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjær, M. and Bangsbo, J. (2003a). Muscle metabolites during a football match in relation to a decreased sprinting ability. In *Book of Abstracts, 5th World Congress of Science and Football.* (edited by F. Alves, J. Cabri, J.A. Diniz, and T.Reilly), pp. 227. Lisbon, Portugal: Editorial Gymnos.

Kuipers, H. (1998). Training and overtraining: an introduction. *Medicine and Science in Sports and Exercise,* **30**, 1137-1139.

Labsy, Z., Collomp, K., Frey, A. and De Ceauriz, J. (2004). Assessment of maximum aerobic velocity in soccer players by means of an adapted robust field test. *Sports Medicine and Physical Fitness,* **44**, 355-382.

Leatt, P. (1986). The effect of glucose polymer ingestion on skeletal muscle glycogen depletion during a soccer match play and its resynthesis following a match (MSc thesis). Toronto: University of Toronto.

Leger, L. and Boucher, R. (1980). An indirect continuous running multisatge field test: The Universite De Montreal Track Test. *Canadian Journal of Applied Sports Science,* **5**, 77-84.

Leiper, J.B. and Molla, A.M. (2003). Effects on health of fluid restriction during fasting in Ramadan. *European Journal of Clinical Nutrition,* **57** (suppl. 2), 530-538.

Lemmink, K.A.P.M., Visscher, C. and Lamberts, R.P. (2004). The interval shuttle run test for intermittent sport players: Evaluation of reliability. *Journal of Strength and Conditioning Research,* **18**, 821-827.

Little, T. and Williams, A. (2003). Specificity of acceleration, maximum speed and agility in professional soccer players. In *Book of Abstracts, 5th World Congress of Science and Football.* (edited by F. Alves, J. Cabri, J.A. Diniz, and T.Reilly), pp.144-5. Lisbon, Portugal: Editorial Gymnos.

Little, T. and Williams, A.G. (2006). Suitability of soccer training drills for endurance training. *The Journal of Strength and Conditioning Research,* **20**, 316-319.

Luhtanen, P. (1994). Biomechanical aspects. In *Football (Soccer)* (edited by B. Ekblom), pp 59-77. Oxford: Blackwell Scientific.

Macdonald, I.A. and Webber, J. (1995). Feeding, fasting, and starvation: factors affecting fuel utilisation. *Proceedings of The Nutritional Society,* **54**, 267-274.

McGregor, S.J., Nicholas, C.W., Lakomy, H.K. and Williams, C. (1999). The influence of intermittent high-intensity running and fluid ingestion on the performance of a soccer skill. *Journal of Sports Sciences*, **17**, 895-903.

MacLaren, D., Davids, K., Isokawa, M., Mellor, S. and Reilly, T. (1988). Physiological strain of 4-a side soccer, in *Science and Football III* (edited by T.Reilly, A. Lees, K. Davids, and W.J. Murphy). pp 76-80. London: E and F Spon.

Magal, M., Webster, M.J., Sistrunk, L.E., Whitehead, M.T., Evans, R.K. and Boyd, J.C. (2003). Comparison of glycerol and water hydration regimens on tennis related performance. *Medicine and Science in Sports and Exercise*, **35**, 150-156.

Malik, G.M., Mubarik, M. and Hussain, T. (1996). Ramadan fasting-effects on heath and disease. *Journal of the Association of Physicians of India*, **44**, 332-334.

Mangine, R.E., Noyes, F.R. and Mullen, M.P. (1990). A physiological profile of the elite soccer athlete. *Journal of Orthopaedic Sports and Physical Therapy*, **12**, 147-152.

Martin, B.J. (1981). Effects of sleep deprivation on tolerance of prolonged exercise. *European Journal of Applied Physiology and Occupational Physiology*, **47**, 345-354.

Martin, E.A. (1998). *Concise Colour Medical Dictionary*. Oxford: Oxford University Press.

Maughan, R. and Shirreffs, S. (2004). Exercise in the heat: Challenges and opportunities. *Journal of Sports Sciences*, **22**, 917-927.

Maughan, R., Gleeson, M. and Greenhaff, P.L. (1997). *Biochemistry of Exercise and Training*. Oxford: Oxford University Press.

Maughan, R.J. (2003). Impact of mild dehydration on wellness and on exercise performance. *European Journal of Clinical Nutrition*, **57**, S19-S23.

Mayhew, S.R. and Wenger, H.A. (1985). Time-motion analysis of professional soccer. *Journal of Human Movement Studies*, **11**, 49-52.

Maughan, R.J. and Leiper, J.B. (1994). Fluid replacement requirements in soccer. *Journal of Sports Sciences*, **17**, 895-903.

Maughan, R.J., Watson, P., Evans, G.H., Broad, N. and Shirreffs, S.M. (2007). Water balance and salt losses in compeitive football. *International Journal pf Sports Nutrition and Exercise Metabolism*, **17**, 583-594.

McArdle, W.D., Katch, F.I. and Katch, V.L. (1996). *Exercise Physiology.* (4th Edition). Champaign, IL: Human Kinetics.

McConnell, G.K., Costill, D.L. and Widrick, J.J. (1993). Reduced training volume and intensity maintain aerobic capacity but not performance in distance runners. *International Journal of Sports Medicine,* **14**, 33-7.

Mccutcheon, M.C., Sticha, S.A., Giese, M.D. and Nagle, F.J. (1991). A further analysis of the 12-Minute run prediction of maximal aerobic power. *Research Quarterly for Exercise and Sport,* **61**, 280-283.

McGregor, S.J., Nicolas, C.W., Lakomy, H.K.A. and Williams, C. (1999a). The influence of intermittent high intensity shuttle run and fluid ingestion on performance of a soccer skill. *Journal of Sports Sciences,* **17**, 895-903.

McMillian, K., Helgerud, J., Macdonald, R. and Hoff, J. (2005). Physiological adaptations to soccer specific endurance training in professional youth soccer players. *British Journal of Sports Medicine,* **39**, 273-277.

Medbo, J., Mohn, A., Tabata, I., Bahr, R., Vaage, O. and Sejersted, O. (1988). Anaerobic capacity determined by maximal accumulated O_2 deficit. *Journal Of Applied Physiology,* **64**, 50-60.

Met Office: Online: http://metoffice.gov.uk/education/secondary/students/beaufort.html.

Mohr, M., Krustrup, P. and Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences,* **21**, 519-528.

Mohr, M., Krustrup, P. and Bangsbo, J. (2003b). Physical preparation for the world cup using sub-maximal Yo-YO intermittent endurance test to evaluate training status. In *Book of Abstracts, 5th World Congress of Science and Football.* (edited by F. Alves, J. Cabri, J.A. Diniz, and T.Reilly), pp. 40. Lisbon, Portugal: Editorial Gymnos.

Mohr, M., Krustrup, P. and Bangsbo, J. (2005). Fatigue in soccer: A brief review. *Journal of Sports Sciences,* **23**, 593-599.
Montain, S.J., Maughan, R.J. and Swaka, M.N. (1996). Heat acclimatization strategies for the 1996 Summer Olympics. *Athletic Therapy Today,* **1**, 42-46.

Montain, S.J. and Coyle, E.F. (1992). Influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. *Journal of Applied Physiology,* 73, 1340-1350.

Morgan, D.W., Bransford, D.R., Costill, D.L., Daniels, J.T., Howley, E.T. and Krahenbuhl, G.S. (1995). Variation in the aerobic demand of running among trained and untrained subjects. *Medicine and Science in Sports and Exercise,* **27**, 404-409.

Morris, J.G., Nevill, M.E., Lakomy, H.K.A., Nicholas, C. and Williams, C. (1998). Effect of a hot environment on performance of prolonged intermittent high intensity shuttle running. *Journal of Sports Sciences,* **16**, 677-686.

Mujika, I. and Padilla, S. (2000). Detraining: loss of training induced physiological and performance adaptations: Part 1. Short term insufficient training stimulus. *Sports Medicine,* **30**, 79-87.

Mujika, I. and Padilla, S. (2001). Cardiorespiratory and metabolic characteristics of detraining in humans. *Medicine and Science in Sports and Exercise,* **33**, 413-421.

Murray, R. (1998). Rehydration strategies-balancing substrate, fluid, and electrolyte provision. *International Journal of Sports Medicine,* **19**, S133-S135.

Mustafa, K.Y. and Mahmoud, N.E.A. (1979). Evaporative water loss in African players. *Journal of Sports Medicine and Physical Fitness,* **19**, 181-183.

Nichols, J.F., Phares, S.L. and Buono, M.J. (1997). Relationship between blood lactate responses to exercise and endurance performance in competitive female cyclists. *International Journal of Sports Medicine,* **18**, 458-463.

Nicholson, R.M. and Sleivert, G.G.(2001). Indices of lactate threshold and their relationship with 10-km running velocity. *Medicine and Science in Sports and Exercise,* **33**, 339-342.

Noakes, T.D. and St Clair Gibson, A. (2004). Logical limitations of the catastrophe models of fatigue during exercise in humans. *British Journal of Sports Medicine,* **38**, 648-649.

Nomani, M.Z., Khan, A.H., Shahda, A.H., Nomani, A.K. and Sattar, S.A. (2005). Predicting serum gastrin levels among men during Ramadan Fasting. *Eastern Mediterranean Health Journal,* **11**, 119-125.

Nonogaki, K. (2007). Ghrelin and feedback systems. *Vitamins and Hormones,* **77**, 149-170.

Orchard, J., Marsden, J., Lord, S. and Garlick, D. (1997). Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *The American Journal of Sports Medicine,* **25**, 81-85.

Osnes, J. and Hermansen, L. (1972). Acid based balance after maximal exercise of short duration. *Journal of Applied Physiology*, **32**, 59-63.

Oyono-Enquelle, S., Marbach, J., Heitz, A., Ott, C., Gartner, M., Pape, A., Vollmer, J.C. and Freund, H. (1990). Lactate removal ability and graded exercise in humans. *Journal of Applied Physiology*, **68**, 905-911.

Parkhouse, W.S. and Mckenzie, D.C. (1984). Possible contribution of skeletal muscle buffers to enhanced anaerobic performance : a brief review. *Medicine and Science in Sports and Exercise*, **16**, 328-338.

Pate, R.R. and Kirska, A. (1984). Physiological basis of the sex difference in cardiorespiratory endurance. *Sports Medicine*, **1**, 87-98.

Pauole, K., Madole, K., Garhammer, J., Lacourse, M. and Rozenek, R. (2000). Reliability and validity of the T-Test as a measure of agility, leg power and leg speed in college – aged men and women. *The Journal of Strength and Conditioning Research*, **14**, 443-450.

Pilcher, J.J. and Huffcutt, A.I. (1996). Effects of sleep deprivation on performance . A meta-analysis. *Sleep*, **19**, 318-326.

Pilegaard, H., Domino, K., Noland, T., Juel, C., Hellsten, Y., Halestrap, A.P. and Bangsbo, J. (1999). Effect of high intensity exercise training on lactate/H^+ transports capacity in human skeletal muscle. *American Journal of Physiology Endocrinology and Metabolism*, **276**, E255-E261.

Platt, D., Maxwell, A., Horn, R., Williams, M. and Reilly, T. (2001). Physiological and technical analysis of 3 v 3 and 5 v 5 youth football matches. *Insight-The FA Coaches Association Journal*, **4**, 23-24.

Pyke, F.S. and Hahn, A. G. (1980). Body temperature regulation in summer football. *Sports Coach*, **4**, 41-3.

Pyne, D., Boston, T., Martin, D. and Logan, A. (2000). Evaluation of the Lactate pro blood lactate analyser. *European Journal of Applied Physiology*, **82**, 112-116.
Rahkila, P. and Luhtamen, P. (1991). Physical fitness profile of Finnish national soccer teams candidates. *Science and Football*, **5**, 30-33.

Ramadan, J., Telahoun, G., Al-Zaid, N.S. and Barac-Nieto, M. (1999). Responses to exercise fluid, and energy balances during Ramadan in sedentary and active males. *Nutrition*, **15**, 735-739.

Ramadan, J.M. and Barac-Nieto, M. (2000). Cardio-respiratory responses to moderately heavy aerobic exercise during the Ramadan fasts. *Saudi Medical Journal*, **21**, 238-244.

Ramsbottom, R., Brewer, J. and Williams, C. (1988). A progressive shuttle run test to estimate maximal oxygen uptake. *British Journal of Sports Medicine*, **22**, 141-144.

Reilly, T. (1987). Circadian rhythms and exercise: In *Exercise Benefits Limits and Adaptations.* (edited by D. Macleod, R.J. Maughan, M. Nimmo, T. Reilly and C. Williams). pp. 346-366. London: E & FN Spon.

Reilly, T. (1997) Aerobic Training. *Insight-The F.A. Coaches Association Journal,* **2**, (1) pp-30-31.

Reilly, T. (2000). Temperature and performance in heat. In *ABC of Sports Medicine.* (edited by M. Harries, G. McLatchie, C. Williams and J. King, J). pp 68-71. London: BMJ Books.

Reilly, T. (1990). Football. In *Physiology of Sports.* (edited by T.Reilly, N.Secher, P.Snell, and C.Williams), pp. 371-426. London: E & FN Spon.

Reilly, T. (2003). Interpreting the training stimulus. *Insight. The FA Coaches Association Journal,* **3**, 46-47.

Reilly, T. (2005). An ergonomics model of the soccer training process. *Journal of Sports Sciences,* **23**, 561-77.

Reilly, T. and Bryant, J. (1986). Dissociation of lactate and ventilatory thresholds by glycogen loading. *Journal of Human Movement Studies*, **12**, 195-200.

Reilly, T. and Ekblom, B. (2005). The use of recovery methods post-exercise. *Journal of Sports Sciences,* **23**, 619-627.

Reilly, T. and Piercy, M. (1994). The effect of partial sleep deprivation on weight lifting performance. *Ergonomics,* **37**, 107-15.

Reilly, T. and Thomas, V. (1979). Estimated energy expenditures of professional association footballers. *Ergonomics,* **22**, 541-548.

Reilly, T. and Thomas, V. (1976). A motion analysis of work-rate in different positional roles in professional match play. *Journal of Human Movement Studies,* **2**, 87-97.

Reilly, T. and Thomas, V. (1977). Effects of a programme of pre-season training on the fitness of soccer players. *British Journal of Sports Medicine,* **17**, 401-412.

Reilly, T. and Waterhouse, J. (2005). *Sport Exercise and Environmental Physiology.* London: Elsevier Churchill.

Reilly, T. and White, C. (2004). Small-sided games as an alternative to interval-training for soccer players. *Journal of Sports Sciences*, **22**, 559.

Reilly, T. and Waterhouse, J. (2007). Altered sleep-wake cycles and food intake: The Ramadan Model. *Physiology Behaviour*, **28**, 219-228.

Reilly, T. and Williams, M. A. (2003). *Science and Soccer.* (2nd Edition). London: Routledge.

Reilly, T. (2003). Fitness and the start of the season. *Insight. The FA Coaches Association Journal*, **4**, 69.

Rhea, M.R., Ball, S.D., Phillips, W.T. and Burkett, L.N. (2002). A comparison of linear and daily undulating periodized programs with equated volume and intensity. *Journal of Strength. Journal of Strength and Conditioning Research*, **16**, 250–255.

Rhea, M.R., Landers, D.M., Alvar, B.A. and Arent, S.M. (2003). The effects of competition and the presence of an audience on weight lifting performance. *Journal of Strength and Conditioning Research*, **17**, 303-306.

Rico-Sanz, J., Frontora, W.R., Mole, P.A., Rivera, M.A., Rivera-Brown, A. and Meredeth, (1998). Dietary and performance assessment of elite soccer players during a period of intense training. *International Journal of Sport Nutrition*, **8**, 230-240.

Rico-Sanz, J., Zehnder, M., Buchli, R., Dambach, M. and Boutellier, U. (1999). Muscle glycogen degradation during simulation of a fatiguing soccer match in elite soccer players examined noninvasively by ^{13} C-MRS. *Medicine and Science in Sports and Exercise*, **31**, 1587-1593.

Rienzi, E., Drust, B., Reilly, T., Carter, J.E. and Martin, A. (1998). Investigation of anthropometric and work rate profiles of elite South American International players. *Journal of Sports Medicine and Physical Fitness*, **40**, 162-169.

Rio, G.S., Nanni, G., Tavana, R. and Tencone. (2003). Epidemiology of ACL ruptures in first league soccer players. In *Book of Abstracts, 5th World Congress of Science and Football.* (edited by F. Alves, J. Cabri, J.A. Diniz, and T.Reilly), pp. 227. Lisbon, Portugal: Editorial Gymnos.

Robinson, F. (1991). *Atlas of the Islamic World Since 1500.* Oxfordshire, England: Andromeda Oxford Limited.

Roehrs, T. and Roth, T. (2007). Caffeine: Sleep and daytime sleepiness. *Sleep Medicine Reviews (epub ahead of print).*

Roitman, J.L., Kelsey, M., LaFontaine, T.P., Southard, D.R., Williams, M.A. and York, T. (1998). *ACSM's Resource Manual: For Guidelines for Exercise Testing and Prescription* (3rd Edition). Baltimore: Williams & Wilkins.

Roky, R., Iraki, L., Hajkhlifa, R., Ghazal, N.L. and Hakkou, F. (2000). Daytime alertness, mood, psychomotor performances, and oral temperature during Ramadan intermittent fasting. *Annals of Nutrition and Metabolism,* **44**, 101-107.

Roper, R.L. (1998). Incorporating agility training and backward movement into a Plyometric program. *Strength and Conditioning,* **12**, *60-63.*

Rosen, O., Holm, K., Staff, H., Opstad, P.K., Pedersen, B.K. and Bahr, R. (2001). No effect of seasonal variation in training load on immuno-endocrine responses to acute exhaustive exercise. *Scandinavian Journal of Medicine and Science in Sports,* **11**, 141-148.

Ross, M.D., Langford, B. and Whelan, P.J. (2002). Test-retest reliability of 4 single leg hop tests. *Journal of Strength and Conditioning Research,* **16**, 617-622.

Rowell, L.B. (1983). Cardiovascular aspects of human thermoregulations. *Circulatory Research,* **52**, 367-79.

Sahlin, K. (1986). Muscle fatigue and lactic acid accumulation. *Acta Physiol Scand Suppl,* **556**, 83-91.

Saltin B. In *Exercise Physiology.* (4th Edition). (edited by W.D. McArdle, F.I. Katch and V.L. Katch 1996). pp 396-397. Champaign, IL: Human Kinetics.

Saltin, B. (1964). Aerobic and anaerobic work capacity after dehydration. *Journal of Applied Physiology,* **19**, 1114-1118.

Saltin, B. (1973). Metabolic fundamentals in exercise. *Medicine and Science in Sports and Exercise,* **13**, 99-107.

Saltin, B. and Costill, D.L. (1988). Fluid and electrolyte balance during prolonged exercise. In *Exercise, Nutrition, and Metabolism* (edited by E.S. Horton and R.L. Terjung). pp 150-158. New York: Macmillian.

Samaros, G. Energy usage during a football match. In *Proceedings of the 1st International Congress on Sports Medicine Applied to Football.* (Edited by L. Vecciet). Pp 795-801. Rome, 1980.

Sands, W.A., McNeal, J.R., Ochi, T.L., Urbanek, T.C., Jemni, N. and Stone, M.E. (2004). Comparison of the Wingate Bosco repeated Jumps Anaerobic Tests. *The Journal of Strength and Conditioning Research,* **18**, 810-815.

Sassi, R., Reilly, T. and Impellizzeri, F. (2004). A comparison of small sided games and interval training in elite professional soccer players. *Journal of Sports Sciences*, **22**, 562.

Sawka, M.N., Young, A.J., Francesconi, R,P., Muza, S.R. and Pandolf, K.B. (1985). Thermoregulatory and blood responses during exercise at graded hypohydration levels. *Journal of Applied Physiology*, **59**, 1394-1401.

Sawka, M.N., Young, A.J., Latza, W.Z., Neufer, P.D., Quigley, M.D. and Pandolf, K.B. (1992). *Human tolerance to heat strain during exercise: Influence of hydration. Journal of Applied Physiology*, **73**, 368-378.

Shanks, N.J., Ansari, M. and Al-Kalai, D. (1994). Road traffic accident in Saudi Arabia. *Public Health*, **108**, 27-34.

Sharp, R.L., Costill, D.L., Fink, W.J. and King, D.S. (1986). Effects of eight weeks of bicycle ergometer sprint training on muscle buffer capacity. *International Journal of Sports Medicine*, **7**, 13-17.

Shephard, R.J. (1999). Biology and medicine of soccer: an update. *Journal of Sports Sciences*, **17**, 757-786.

Shepley, B., MacDougall, J.D. and Cipriano, N. (1992). Physiological effects of tapering in highly trained athletes. *Journal of Applied Physiology*, **72**, 706-711.

Shimojo, N., Naka, K., Uenoyama, H., Hamamoto, K., Yoshioka, K. and Okuda, K. (1993). Electrochemical assay system with single-use electrode strip for measuring lactate in whole blood. *Clinical Chemistry*, **39**, 2312-2314.

Shipp, N.J., Scroop, G.C., Jackson, S.C., Holmes, M.D., Thornton, A.T. and Gore, C.J.(2004). Rectal temperature correction overestimates the frequency of exercise-induced hypoxemia. *Medicine and Science in Sports and Exercise*, **36**, **7**, 1111-6.

Shirreffs, S.M. and Maughan, R. (1998a). Urine osmolality and conductivity as markers of hydration status. *Medicine and Science in Sports and Exercise*, **30**, 1598-1602.
Siff, M. (2003). *SUPERTRAINING*. (6^{th} Edition). Denver, USA: Supertraining Institute.

Smith, D.J. (2003). A Framework for understanding the Training Process Leading to Elite Performance. *Sports Medicine*, **33**, 1103-1126.

Smodlaka, V.N. (1978). Cardiovascular aspects of soccer. *Physician and Sports Medicine*, **6**, 66-77.

Spurr, G.B., Prentice, A.M., Murgatroyd, D.R., Goldberg, G.R., Reina, J.C. and Christman, N.T. (1988). Energy Expenditure from minute by minute heart Rate Recording: Comparison with indirect calorimetry. *American Journal of Clinical Nutrition*, **48**, 552-559.

Stolen, T., Chamari, K., Castagna, C. and Wisløff, E. (2005). Physiology of soccer: an update. *Sports Medicine*, **35**: 501-536.

Stone and Conley (1994). In *The Essentials of Strength Training and Conditioning: National strength and Conditioning Association.* (edited by T. Baechle). pp. 67-85 Champaign, IL: Human Kinetics.

Stone, M.H., Pierce, K., Godsen, R., Wilson, D., Blessing, D., Rozenek, R. and Chromiak, J. (1987). Heart rate and lactate levels during weight-training in trained and untrained men. *The Physician and Sports Medicine*, **15**, 97-105.

Strudwick, A., Reilly, T. and Doran, D. (2002). Anthropometric and fitness characteristics of elite players in two football codes. *Journal of Sports Medicine and Physical Fitness*, **42**, 239-242.

Strudwick, T. and Reilly, T. (2001). Work-rate profiles of premier league football players. *Insight, The F.A. Coaches Association Journal,* **2**, 28-29.

Svensson, M. and Drust, B. (2005). Testing soccer players. *Journal of Sports Sciences,* **23**, 601-618.

Sweileh, N., Schnitzler, A., Hunter, G.R. and Davis, B. (1992). Body composition and energy metabolism in resting and exercising Muslims during Ramadan fast. *The journal of Sports Medicine and Physical Fitness,* **32**, 156-163.

Szlyk, P.C., Sils, I.V. and Francesconi, R.P. (1990). Patterns of human drinking effects of exercise, water temperature, and food consumption. *Aviat Space Environment and Medicine,* **61**, 43-48.

Taylor, D.J., Bore, P.J., Styles, P., Gadian, D.G. and Radda, G.K. (1983). Bioenergetics of intact human muscle. A ^{31}P nuclear magnetic resonance study. *Molecular Biology. Medicine,* **1**, 77–94.

Thomas, D. E. (1994). Carbohydrate loading before exercise, effect of glycemic index. *International Journal of Sports Nutrition*, **4**, 261-273.

Thomas, J.R., and Nelson, J.K. (1996). *Research Methods in Physical Activity. (3rd Edition).* Champiagn, IL: Human Kinetics.

Thomas, V. and Reilly, T. (1979). Fitness Assessment of English league soccer players through the competitive season. *British Journal of Sports Medicine*, **13**, 103-109.

Tortora, G.J. and Grabowski, R. (1996). *Principles of Anatomy and Physiology.* (8th Edition). New York, NY: HarperCollins.

Tumilty, D. (1993). Physiological characteristics of elite soccer players. *Sports Medicine,* **16**, 80-96.

Van Itallie, T.B. and Yang, M. (1977). Diet and weight loss. *New England Journal of Medicin,* **297**, 1158-1161.

VanGool, D., Van Gerven, D. and Boutmans, J.(1988). The physiological load imposed on soccer players during real match play. In *Science and Football III* (edited by T. Reilly, A, Lees, K. Davids and W.J. Murphy). pp 51-59. London: E and F Spon.

Venter, R.E., Terblannche, E., Page, C. and Kroff, J. (2005). The effect of backward locomotion training on the body composition and cardiorespiratory fitness of women. *International Journal of Sports Medicine,* **26**, 214-219.

Verheijen, R. (1998). *Conditioning for Soccer.* Spring City, PA: Reedswain.

Verheijen, R. (2003). Periodisation in football: preparing the Korean national team for the 2002 World Cup. *Insight: The FA Coaches Association Journal.* **6**, 30-34.

Vincent, W. J. (2005). *Statistics in Kinesiology.* (*3rd Edition*) Champaign, IL: Human Kinetics.

Weltman, A. (1995). *The blood lactate response to exercise.* Champaign, Illinois: Human Kinetics.

Wiemann, K. and Tidow, G. (1995). Relative activity of hip and knee extensors in sprinting – implications of training. *New Studies in Athletes,* **10**, 29-49.

Williams, C. (1990). Metabolic aspects of exercise. In *Physiology of Sports.* (edited by T. Reilly, N. Secher, P. Snell and C. Williams). pp. 1- 40. London: E & FN Spon.

Wilson, D. (2001). The physiological basis of speed-endurance. *Insight, F.A. Coaches Association Journal,* **3**, 36-37

Wilson, M.M.G. and Morley, J.E. (2003). Impaired cognitive function and mental performance in mild dehydration. *European Journal of Clinical Nutrition,* **57**, 524-529.

Wisløff U, Helgerud, J. and Hoff, J. (1998) Strength and endurance of elite soccer players. *Medicine and Science in Sports Exercise,* **30**, 462-467.

Withers, R.T., Maricic, Z., Wailewski, S. and Kelly, K. (1982). Match Analysis of Australian professional soccer players. *Journal of Human Movement Studies,* **8**, 159-76.

Withers, R., Sherman, W., Clark, D., Esselbach, P., Nolan, S., Mackay, M., and Brinkman, M. (1991). Muscle metabolism during 30, 60, and 90 s of maximal cycling on an air-braked ergometer. *European Journal of Applied Physiology,* **63**, 354-362.

Wragg, C.B., Maxwell, N.S. and Doust, J.H. (2000) Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. *European Journal of Physiology,* **83**, 77-83.

Wragg, C.B., Maxwell, N. and Doust, J. H. (2001). Development of a multidirectional soccer specific field test of repeated sprint ability: Validity and reliability. *Journal of Sports Sciences,* **8**, 609-610.

www.GamesBids.com, (2007). Data accessed Internet.

Yessis, M. (2001). *Women's Soccer: Using Science to Improve Speed.* Terre Haute, In: Wish Publishing.

Young, W.B., McLean, B. and Ardagna, J. (1995). Relationship between strength qualities and sprinting performance. *Journal of Sports Medicine and Physical Fitness.* **35**, 13-19.

Young, W., MacDonald, C., Heggen, T. and Fitzpatrick, J. (1997). An evaluation of the specificity, validity, and reliability of jumping tests. *Journal of Sports Medicine and Physical Fitness.***37**, 240-245.

Young, W.B., McDowell, M.H. and Scarlett, B.J. (2001). Specificity of sprint and agility training methods. *Journal of Strength and Conditioning Research,* **15**, 3, 315-319.

Yule, E., Kaminsky, L.A., Sedlock, D.A., King, B.A. and Whalley, M.H. (1996). Inter-laboratory reliability of VO_2 max and sub maximal measurements. *Medicine and Science in Sports and Exercise,* **28**, (Suppl): S15-S87.

Zatsiorsky, V.M. (1995). *Science and Practice of Strength Training.* Champaign, IL: Human Kinetics.

Zerguini, Y., Kirkendall, D., Junge, A. and Dvorak, J. (2007). Impact of Ramadan on physical performance in professional soccer players. *British Journal of Sports Medicine,* **41**, 398-400.

Appendices

Appendix 1

Study 2

1.1 Score sheet for VO_2max

Score Sheet for VO_2max

Level	Shuttle														
1	1	2	3	4	5	6									
2	1	2	3	4	5	6	7								
3	1	2	3	4	5	6	7								
4	1	2	3	4	5	6	7	8							
5	1	2	3	4	5	6	7	8							
6	1	2	3	4	5	6	7	8	9						
7	1	2	3	4	5	6	7	8	9						
8	1	2	3	4	5	6	7	8	9	10					
9	1	2	3	4	5	6	7	8	9	10					
10	1	2	3	4	5	6	7	8	9	10					
11	1	2	3	4	5	6	7	8	9	10	11				
12	1	2	3	4	5	6	7	8	9	10	11				
13	1	2	3	4	5	6	7	8	9	10	11	12			
14	1	2	3	4	5	6	7	8	9	10	11	12			
15	1	2	3	4	5	6	7	8	9	10	11	12			
16	1	2	3	4	5	6	7	8	9	10	11	12	13		
17	1	2	3	4	5	6	7	8	9	10	11	12	13		
18	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
21	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

1.2 Data recording sheet for VO_2max

Doha College - Test Data-Sheet-Group 1-Inside

Date:				BLEEP TEST			Predicted	Vo2 Max	
Squad No	Player	Position	D.O.B	level No	Shuttle No	Max HR	Max HR (220-Age)	ml.kg-1.min-1	
1		Rec Sports							
2		Rec Sports							
3		Rec Sports							
4		Rec Sports							
5		Rec Sports							
6		Rec Sports							
7		Rec Sports							
8		Rec Sports							
9		Rec Sports							
10		Rec Sports							
11		Rec Sports							
12		Rec Sports							
13		Rec Sports							
14		Rec Sports							
15		Rec Sports							
16		Rec Sports							
17		Rec Sports							
18		Rec Sports							
19		Rec Sports							
20		Rec Sports							
21		Rec Sports							
22		Rec Sports							
23		Rec Sports							
24		Rec Sports							
25		Rec Sports							
	Total/squad NO =								
	Average =								

1.3 Score sheet for YYIRT

Yo-Yo Intermittent Recovery Test - Level 1

Final - 2 x 20m interval that the individual does not complete is not included !!

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

1.4 Data recording sheet for YYIRT

Doha College - Test Data-Sheet-Group 1inside

Squad No	Player	Date	Position	Speed level No	Shuttle No	Max HR	Predicted Max HR (220-Age)	Total Distance	
1			REC-Sports						
2			REC-Sports						
3			REC-Sports						
4			REC-Sports						
5			REC-Sports						
6			REC-Sports						
7			REC-Sports						
8			REC-Sports						
9			REC-Sports						
10			REC-Sports						
11			REC-Sports						
12			REC-Sports						
13			REC-Sports						
14			REC-Sports						
15			REC-Sports						
16			REC-Sports						
17			REC-Sports						
18			REC-Sports						
19			REC-Sports						
20			REC-Sports						
21									
22									
23									
24									
	Total/squad NO =								
	Average =								

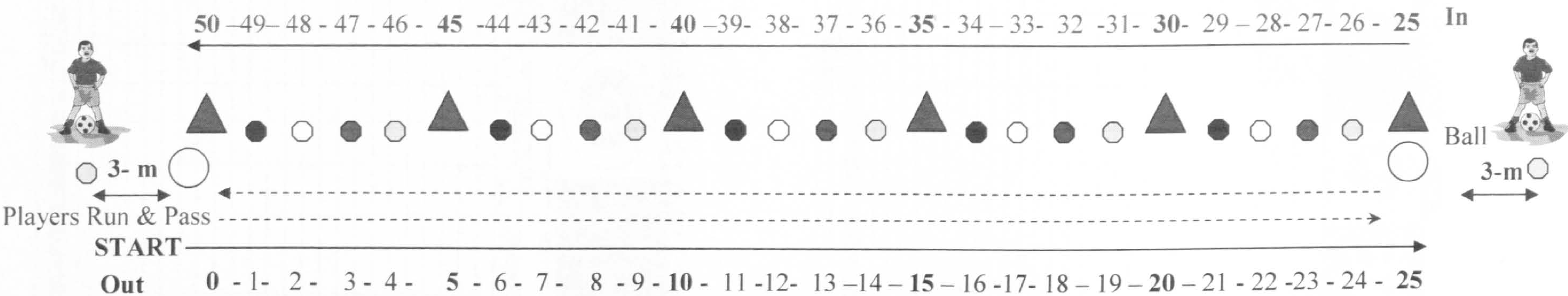
1.5 LAST score and data recording sheet

Liverpool Anaerobic Speed Test (LAST)

Squad: ………………………………... Date:…/……/…

Name:………………………………………………… Date of Birth:……………….

Playing Position:……………………… Environment:……………………………



	Total Score m			50m	100m	150m	200m	250m	300m	350m	+
Repetition 1 =	+	=	m								………
Repetition 2 =	+	=	m								………
Repetition 3 =	+	=	m								………

1. **Best score** = ______ **m**
2. **Total distance** = **R1:** ____ **m + R2:** _____ **m + R3:** ____ **m** = ____ **m**
3. **Mean distance** (total distance /3) = ____ **m**
   Estimated max heart rate = ____ **beats.min^{-1} : 90-95% heart rate max** = _____ **beats.min^{-1}** - ____ **beats.min^{-1}**
4. **Heart Rate** (beats.min^{-1}) = **R1:** ____ **beats.min^{-1}, R2:** ____ **beats.min^{-1}, R3:** ____ **beats.min^{-1}**

1.6 Data recording sheet for vertical power

Doha College - Test Data-Sheet-Group 1-Outside

AGE GROUP:	No. of Days Since Last Game:
DATE:	No. of Games in Previous 7 days:
Location & Environment:	No. of Days Since Last Training Session:
Temperature: C	No. of Training Sessions in Previous 7 Days:
Humdity: %	

Vertical Power				JUMP TESTS								
				Rocket Jump			CMJ (no arms)			CMJ (with arms)		
Date:				Height (cm)			Height (cm)			Height (cm)		
Squad NO	PLAYER	DATE of BIRTH	Position	1	2	Best	1	2	Best	1	2	Best
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
24												
25												
			Total/squad NO =									
			Average =									

1.7 Data recording sheet for horizontal power

Doha College- Test Data-Sheet-Group 1-Outside

Date:			Horizontal power forwards										Backward sprint		
Horizontal Power			Standing Broad Jump				Single leg-hop (10m)						static start 10m		
		Position	Distance cm				Time (sec) Left leg			Time (sec) Right leg			Time (sec)		
Squad NO	PLAYER	Test	1	2	3	Best	1	2	Best	1	2	Best	1	2	Best
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
		Average =													

1.8 Data recording sheet for speed and agility

Doha College - Test Data-Sheet-Group 1-Outside

Date:			SPEED TEST									AGILITY TEST					
	Speed & Agility		10m			30m			Flying 20m			Run 1			Run 2		
Squad NO	PLAYER	Position	Time (sec)			Time (sec)			Time (sec)			Time (sec)			Time (sec)		
		Test	1	2	Best	1	2	Best	1	2	Best	1	2	Best	1	2	Best
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	
21																	
22																	
23																	
24																	
25																	
		Total/squad NO =															
		Average =															

1.9 Equipment List for tests

1.10 Equipment for test day-1

1. Button cones (red & yellow)
2. 50 m tape measure
3. Whistle
4. Stop-watch
5. Radio cassette player (wire and extension for indoor)
6. New batteries/extra batteries
7. Yo-Yo Intermittent Recovery tape
8. Newtest system and jump-mat
9. Test data recording sheets
10. Clip boards
11. Pens
12. Thermometer (climate), anemometer (wind)
13. HR-monitors (Polar Team System) X 20

1.11 Equipment list for test day-2

1. Button cones (red & yellow)
2. 50 m tape measure
3. Whistle
4. Stop-watch
5. Radio/CD cassette player (wire and extension for indoor)
6. New batteries/extra batteries
7. Multi-stage Fitness Test-CD
8. Newtest system and jump-mat
9. Test data recording sheets
10. Clip boards
11. Pens
12. Thermometer (climate), anemometer (wind)
13. HR-monitors (Polar Team System) X 20

1.12 Equipment list for test day-3

1. Button cones (red & yellow)
2. Foot starter button cones X 2, placed 1 m behind line.
3. Finish cones X 2, at 22 m
4. Marker button cones for tripods and cell lights, at 0, 10 m, 20 m
5. Safety button cones for wires (yellow/white)
6. Agility cones – 4 orange/ 4 white
7. 50 m tape measure
8. Whistle
9. Stop-watch
10. Radio/CD cassette player (wire and extension for indoor)
11. New batteries/extra batteries
12. Multi-stage Fitness Test-CD
13. Newtest system 3 x electronical photocells, 3 x tripods
14. Test data recording sheets
15. Clip boards
16. Pens
17. Thermometer (climate), anemometer (wind)

1.13 Equipment List test day-4

1. LAST – 5 sets of tall cones marked
(0/50, 5/45, 10/40, 15, 35, 20/30, 25)

2. 5 sets of small button cones marked
(1/49, 2/48, 3/47, 4/46) (6/44, 7/43, 8/42, 9/41) (11/39, 12/38, 13/37, 14/36)
(16/34, 17/33, 18/32, 19/31) (21/29, 22/28, 23/27, 24/26)

3. 14 soccer-balls
4. 14 marker cones for spotters
5. 50 m tape measure
6. Whistle
7. Stop-watch
8. Radio cassette player (wire and extension for indoor)
9. New batteries/extra batteries
10. Yo-Yo Intermittent Recovery tape
11. LAST-test data recording sheets
12. Clip boards X 6
13. Pens
14. Thermometer (climate), anemometer (wind)
15. Heart rate monitors

Appendix – 2

2.0 Bedtime and wake-up manual sleep diary

Bedtime Sheet

Name:

Ramadan

		Week 1	
Day	Bedtime	Wake-up Time	Sleep Duration
1			
2			
3			
4			
5			
6			
7			

		Week 2	
Day	Bedtime	Wake-up Time	Sleep Duration
1			
2			
3			
4			
5			
6			
7			

		Week 3	
Day	Bedtime	Wake-up Time	Sleep Duration
1			
2			
3			
4			
5			
6			
7			

		Week 4	
Day	Bedtime	Wake-up Time	Sleep Duration
1			
2			
3			
4			
5			
6			
7			

non-Ramadan

		Week 1	
Day	Bedtime	Wake-up Time	Sleep Duration
1			
2			
3			
4			
5			
6			
7			

		Week 2	
Day	Bedtime	Wake-up Time	Sleep Duration
1			
2			
3			
4			
5			
6			
7			

		Week 3	
Day	Bedtime	Wake-up Time	Sleep Duration
1			
2			
3			
4			
5			
6			
7			

		Week 4	
Day	Bedtime	Wake-up Time	Sleep Duration
1			
2			
3			
4			
5			
6			
7			