Physiological and cognitive performance of Futsal and Football referees

A Doctoral Thesis submitted in partial fulfilment of the requirements for the award of Doctor of Philosophy of University of Kent

by

Hawkar Salar Ahmed

Supervisor

Dr Glen Davison

School of Sport and Exercise Sciences

University of Kent

October 2017

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيم

"يَا أَيُّهَا النَّاسُ إِنَّا خَلَقْنَاكُم مِّن ذَكَرٍ وَأُنثَى وَجَعَلْنَاكُمْ شُعُوبًا وَقَبَائِلَ لِتَعَارَفُوا إِنَّ أَكْرَمَكُمْ عِندَ اللَّهِ أَتْقَاكُمْ إِنَّ اللَّهَ عَلِيمٌ خَبِيرٌ"(49:13)

In the name of God (Allah), most gracious and merciful

“Mankind! We created you from a single (pair) of a male and a female, and made you into nations and tribes, so that you might come to know each other. Verily the most honoured of you in the sight of Allah who is the most righteous of you. And Allah has full knowledge and is well acquainted (with all things).” (QS 49: 13)

Acknowledgement

First of all, I owe a lot of gratitude to all Peshmerga who are alive or dead. They make a lot of sacrifices to defence our country. God (Allah) will reward you.
After 4 tough years of stressful life for me, when my scholarship has stopped due to financial constrictions because of the crisis in my country (Kurdistan-Iraq) and the war is still in progress until the moment I am writing my last words to add to this thesis. It is really very tough to concentrate on your PhD and in the same time your mind is somewhere else, therefore it is time to give my acknowledgments to all the people who have supported me in this journey.

First and foremost, thanks God (Allah) for giving me a wonderful mother. Therefore I would like to thank my lovely Mom who has been supporting me with financial help during my studies, especially after the first year of my study when my scholarship has stopped funding me because the crisis in Kurdistan-Iraq. She helped me pay tuition fees, accommodation fees, and my living costs. So many thanks Mom and God (Allah) bless you as I would like to return the favour.

To Evan, my lovely wife, I would like also to thank you for everything you have done for me. She was with me for every single step of my journey during my study and life by motivating me to get higher achievements, besides looking after my sons. So, it is my wife's love, support and sacrifice to enable me to succeed. Big thanks to all my family members, especially my mother, my father, sisters and brothers, for your unconditional love, support and encouragement. This journey would not have been possible without your support.

My special words of thanks should also go to my delightful supervisor Dr. Glen Davison, who has profoundly influenced me and helped me get to this point. Thank you for your support, encouragement, feedback and guidance during my study and your suggestions were always helpful. Indeed, his door was open for me anytime and anywhere and for any questions beside that I would like to raise that point that even though when Dr. Davison was away for a conference or whatever he replied to me in the same day which is highly appreciated. In addition, thanks for teaching me many things, such as stats, SPSS and extra things which was related to my study, which is a part of your kindness, helpfulness and cooperation. Once again thank you so much. Thanks to David Dixon, who is a lecturer at School of Health Sport and Bioscience/University of East London, for your help and cooperation for reviewing all papers that we have submitted together and also thanks for collecting some data for my 2nd study at the FA National Futsal Super League. So many thanks for being such fantastic company.

Even though I have just gotten my financial funding in the first year from my scholarships (KRG) and HCDP I would like to express my gratitude to them because they have chosen me as a candidate to go study English when I could not speak English at all, and also thanks to the University of Sulaimani, School of Physical Education, especially Ali Qader Othman, who is Dean of The Faculty of Physical & Basic Education and Dr Jalal Khdir who is the Head of the School of Physical Education, for administration work and support.

Big thanks to all sport organisations for giving me permission to do my studies on their referees, especially Iraqi football association (Iraqi Futsal Committee), The FA and Kent County Football Association. I would like also thanks to all observers, Ali Saeed, Jason Haywood and Brian Webster, who reviewed all games and assessed decision-making from 1st study. Thanks to Dr Sarko Mohammed who taught me motion analysis software and reviewed a game of the 1st study. Researcher wishes to express his sincere gratitude to all Futsal and football referees for their participation in all studies, especially Iraqi Futsal referees. I would like also to extend my thanks to Asian Football Confederation (AFC), Referees Department and all AFC Elite Futsal refereeing family for their support and understanding my situation during my study besides my refereeing career.

A special thanks to Professor Samuele Marcora for his typical trips and guides for the 2nd study. Here, I wish to thank the numerous friends and colleagues who helped and supported me during the long journey; starting from home thanks to Kurdistan Sewkany the president of the Ashty Sports Club, Saman Kamal, Yassin Abdulmanaf, DR Zanyar Noori, Dr Ary Kamal and Nawzad Mohammed. My sincerest thanks are extended to our friends at the University of Kent especially Dr Akram Amin, Cristina Purcell, Hawbeer Salam, Warhel Mohammed, Ali Astokorki, Borja Martinez-Gonzalez, Chiara Gattoni, Somruthai (Liew) and Ian Farr whom supported me during my study. I want to thank all the people at University of Kent/School of Sport & Exercise Sciences. It was a wonderful place to work and all the staff were very friendly. In addition, Thanks to all friends in London and Medway the place where I lived in the last 4 years, Mr Mariwan Kafrosh, Ferman Rustem, Haval, Xabad Xareb, Akram Salh, Sarhang Aref and Zana for their company and support.

Finally, as always it is impossible to thank everybody who had an influence on my work and I would like to say thanks to everyone who I have mentioned or have not mentioned in this thesis.

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List of abbreviation

Ref(s)	Referee (s)
AR(s)	assistant referee (s)
BL	blood lactate
DM	decision-making
FA	the Football Association
FIFA	Fédération Internationale de Football Association
GLT	Goal Line Technology
HR	heart rate
IFA	Iraqi Football Association
Lapses (SQR XFRM)	Sq Root Transform of Lapses [SQR(Lapses)+SQR(Lapses+1)]
Mean F RT	Average of the fastest 10% of reaction times
Mean RT	Average correct reaction time
Mean S RT	Average of the slowest 10% of reaction times
MF	mental fatigue
RPE	Rating of Perceived Exertion
Total Errors	Total "Incorrect" responses
VAR	Video Assistant referee
SSES	School of Sport & Exercise Sciences
REAG	Research Ethics and Advisory Group
CORT	cortisol
sAA	salivary Alpha(a)-Amylase
sAAR	salivary a-amylase secretion rate
sCS	salivary cortisol secretion
sCSR	salivary cortisol secretion rate
bpm	beat per minute
FNFG	FA National Futsal Group
CNS	central nervous system
KCFA	Kent County Football Association

Declaration

Article published:

Ahmed, H.S., Davison, G., Dixon, D. (2017). Analysis of activity patterns, physiological demands and decision-making performance of Elite Futsal referees during matches. *International Journal of Performance Analysis in Sport*. Accepted Oct 29, 2017. doi: 10.1080/24748668.2017.1399321.

Conference communications:

Poster communications:

Ahmed, H.S.[1], Davison, G.[1], Dixon, D.[2]. Analysis of movement patterns and physiological demands of Elite Futsal referees during matches. (Abstract). *Endurance Research Conference, Chatham, UK.* School of Sport & Exercise Sciences. 2-4 September 2015, University of Kent at Medway, Chatham Maritime, UK. (Poster).

Oral communications:

Ahmed, H.S.[1], Davison, G.[1], Marcora, S.M.[1], Dixon, D.[2]. The effect of a match on psychomotor vigilance in Futsal referees (Abstract). 21st Annual European College of Sport Science Congress, 6th - 9th July 2016, Vienna – Austria. (Oral).

Chapter 1

General Abstract

General Abstract

Reduction of referees' physical performance in the second half of the game has been observed in previous research on football referees. There is very little research addressing Futsal referees. The aim of the present thesis was to investigate physiological, physical and cognitive performance of Futsal and football referees in field and laboratory studies.

The 1st experimental study (Chapter 4) analysed the activity profile and physiological demands of 18 Futsal referees and referee decision-making performance at different stages of the match (e.g. 1st vs 2nd half). In addition, it explored relationships between physical fitness/performance on the Fédération Internationale de Football Association (FIFA) fitness tests, activity profile and decision-making performance. The main findings were that total distance and average heart rate were higher in the first compared to second half but lactate and session RPE were similar. The proportion of correct decisions decreased in the second half (1st half, 91.1 ± 14.9% correct vs 2nd half, 73.3 ± 17.4%, $p = 0.002$). No correlations were evident between FIFA fitness tests and activity profile but the Yo-Yo Intermittent Endurance Test – Level 2 (Yo-Yo IET-2) performance and total distance (clock time) were correlated ($r = 0.720$, $p = 0.019$). Further motion analysis studies are needed to collect data for referees and players during the same matches. The present study also suggests that the traditional FIFA fitness test (and 1000 m run) were poor for assessing Futsal referee-specific fitness, and tests that involve intermittent and/or direction changes, such as the Yo-Yo test or Assistant Referee Intermittent Endurance Test (ARIET), may be more appropriate, although further research is needed on the ARIET in this context.

The 2nd experimental study (Chapter 5) examined whether undertaking a 10-min Psychomotor Vigilance test (PVT) before a match would influence referees' cognitive performance, especially decision-making (DM) to determine the suitability of using it in field-based studies involving real matches. The results showed that the PVT did not affect referees' decision-making or cognitive performance. Hence, the 10- min PVT can be safely used with referees before real competition/in the field.

The 3rd experimental study (Chapter 6) assessed referees' performance on the PVT before and after competitive Futsal matches. The findings showed that, despite changes in BRUMS parameters indicative of a fatigue profile, psychomotor performance was improved after a single match (PVT mean reaction time 248.3 ± 26.2 ms pre- vs 239.7 ± 22.4 ms post-match, $p = 0.023$). It is possible that a more strenuous overall demand would cause different effects, however, the post-match improvement observed here could be used to inform warm-up practices (e.g. optimal duration and intensity) geared towards optimising cognitive performance of referees during matches.

The 4th experimental study (Chapter 7) examined the effect of mental fatigue on referees' physiological responses and cognitive performance during a lab-based intermittent protocol. The main findings were that mental fatigue had a significant negative effect on referees' cognitive performance as assessed by a referee-specific decision-making task (correct decisions, 76.7 ± 7.2% at the beginning of exercise vs 64.6 ± 7.8% at the end, $p < 0.001$), which did not occur in the control trial. PVT performance was also significantly reduced to a greater extend in the mental fatigue, compared to control, condition. This may have implications for optimising referees' preparation and cognitive performance in real matches, which should be explored further.

Overall this thesis has demonstrated that referee performance decreases in the second half in both Futsal and football referees. Further, it provides evidence that this is influenced by mental fatigue. Further investigations on referees' performance and related factors are warranted, along with interventions directed towards improving performance (cognitive and physical) via reducing mental fatigue.

Chapter 2

Introduction

Introduction:

In many competitive team sports the referee is an important part of the match, crucial to a successful competition. Each football association has a "Referee Department", responsible for referee development and aim to improve referees' performance in order to minimise errors during the game. The referee has full authority to enforce the rules and must monitor players' behaviour during the game (FIFA 2017) and take disciplinary action when it is needed. There are three football games that are endorsed and organized by Fédération Internationale de Football Association (FIFA) which are football (soccer), Futsal and Beach Soccer. The word 'Futsal' is a portmanteau of the Portuguese futebol de salão (Portuguese pronunciation: [fut'saw]) which can be translated as "hall football" or "indoor football" (Polidoro et al. 2013) originating from 'futebol de salão' in Portuguese and fútbol de salon or fútbol sala in Spanish (Witzig 2006). Moreover, "five a side football" was originally invented in Uruguay, where it is also traditionally known as Futbol de salon. The popularity of Futsal has grown over the last two decades and most of the FIFA member associations support Futsal. Indeed FIFA, as the international governing body of association football, recently announced that Futsal will replace 11-a-side at the Youth Olympic Football Tournaments Buenos Aires (Argentina) in 2018 (FIFA 2015). It is characterized as an intermittent sport which is played between two teams of five players per team (one goalkeeper and four players).

Referees are required to keep up with match play in order to implement the rules as mentioned above, and hence must be physically and mentally fit to do so. This includes the ability to keep up with play (i.e. be close to incidents and have the speed to move to the correct position quickly), combined with the fitness to maintain this for the duration of the match (typically 80 minutes). Decision-making is a key factor to successful referee performance, as their decisions can influence the outcome of a match (Catteeuw, Helsen, Gilis and Wagemans 2009). However, there is a lack of research investigating cognitive performance for referees in general (Helsen and Bultynck 2004; Weston et al. 2012) and no studies on referee decision-making/performance in Futsal. So, the integration of cognitive demands and physiological demands is key to referee performance and any deficiency in one of these factors may contribute to errors in decisions (i.e. referees' performance).

Evaluation of physical performance of referees in both field and laboratory settings have been conducted (Krustrup and Bangsbo 2001; Castagna, Abt and D'ottavio 2004;

Casajus and Castagna 2007; Taylor *et al.* 2014; Weston, Drust and Gregson 2011; Mallo *et al.* 2012) in order to enhance understanding of the factors that could influence referees' physical and/or cognitive performance. Collecting data during real matches is extremely valuable as this provides information on actual performance in the real environment. However, they are limited to observation, tracking (match analysis) or other methods that rely on interpretation of performance (e.g. decision-making) by others (either in real time or via video playback). However, a real match presents a number of logistical challenges which limit the types of measures and data that can be collected. Also, the precise demands and requirement will vary from match to match. On the other hand, laboratory studies, which aim to simulate the typical demands of a match (or aspects of it) are valuable because they allow control of many variables (e.g. exercise intensity and physiological demand and also environment) so that conditions can be replicated (between subjects but also within subjects/between trials for crossover designs). From a practical perspective this may also allow researchers to re-examine the same athletes over a prolonged time period to monitor training progress or study the effects of interventions on performance in a controlled setting.

The aims of this thesis were to analyse the activity profile and physiological demands of Futsal refereeing, referee decision-making and cognitive performance at different stages of the match (e.g. 1st vs 2nd half). Another aim was to explore relationships between physical fitness/performance on the FIFA fitness tests, activity profile and decision-making performance. Finally, since mental fatigue may influence both physical and cognitive performance, the final aim was to examine the effects of mental fatigue of physiological responses and cognitive performance (e.g. decision-making) in referees (football for this study).

Chapter 3

Literature Review

3.1. Literature review

Components of good referee performance

The components of referee performance include many factors, such physical parameters (e.g. aerobic capacity, agility, repeated sprint ability), psychological components (e.g. ability to perform under pressure, cognitive functions), technical abilities (game awareness and effective positioning), and social factors (e.g. communication, teamwork, ability to command respect). These variables are frequently considered to be important for successful referee performance. This thesis focuses on physiological parameters and cognitive function in football and Futsal referees. The thesis was commenced with the intension of studying only Futsal referees. However this was not feasible and logistically possible for all studies so football referees were used in some studies. There may be subtle differences in cognitive demands between Futsal and football referees. As such, studying both Futsal and football referees may be further useful by providing insight into how subtle differences or changes in cognitive demands influence the parameters of referee performance.

Unlike football, the Futsal referee has only a few seconds to penalise the original offence for a foul or to give an advantage (FIFA 2014, p.94). This may present a greater mental demand or challenge as the referee has a limited amount of time to make his or her decision. Futsal referees typically must make the decision within 2 s (Galan 2016). In football approximately 21 to 25 incidents/referee decision-making events occur per game (Mallo et al. 2012; Mascarenhas et al. 2009) but there is currently no equivalent data in Futsal. However the cognitive demands in Futsal referees may be different to football because the number of fouls in football does not influence the game, unlike Futsal where the total number of fouls can result in a penalty from the second penalty mark (i.e. when exceeding 6 accumulated fouls). In addition, in Futsal numerous incidents may occur, at the same time, in different areas of the pitch. Referees are required to consider both the ‘action area’ (where players are challenging for the ball) and the ‘influence area’ (off the ball movements and actions/incidents). Indeed, one third of all fouls and misconduct occurred in the influence area during the recent FIFA Futsal World Cup 2016 (Galan 2016). For this reason, it is expected that the cognitive demands of Futsal are high. This demand may be a contributing factor in physical and mental performance ability, which may be expected to decrease during exercise as a result of mental and/or physical fatigue. However, there is little previous research on this, and hence a main focus of this thesis.

3.1.1 Demands of Futsal refereeing and activity profile

There are four studies (Rebelo *et al.* 2011; Dixon 2014b; Dixon 2014a; Dixon 2014c) that investigated Futsal referees and their physiological demands and/or fitness test performance. The only research into the match activity profiles of Futsal referees was conducted by Rebelo *et al.* (2011) on 18 elite Portuguese Futsal referees in the 2005–2006 season and pointed out that Futsal referees covered a total distance of 5,892 ± 564 m during Futsal matches, including; walking (2,674 m), jogging (489 m), low speed (719 m), moderate speed (618 m), high speed (259 m), sprint (87 m), backwards (135 m) and sideways (911 m) running with the total number of match activities recorded as 1,395 over 80 min. The total distance covered by sprint and HIR dropped significantly from the first to the last 10-minute period and this could be due to accumulated fatigue in the end of the game (Rebelo *et al.* 2011). Rebelo *et al.* (2011) also evaluated the relationship between fitness test performance and match activity and suggested that the Yo-Yo Intermitted Endurance Test - Level 2 (Yo-Yo IET-2) performance was correlated with the total distance during a game ($r^2 = 0.40$; $p < 0.05$). Rebelo *et al.* (2011) and Dixon (2014b) pointed out that the Yo-Yo IET-2 is a more appropriate test compared to 1000 m endurance test (Pre-July 2016) as it is more sport-specific and relevant to match demands.

Rebelo *et al.* (2011) showed a mean match heart rate (HR) of 149 and 142 bpm in the first and second halves respectively. Dixon (2014a) showed that HR was higher in the first half compared to the second, respectively 155 vs. 149 bpm. Blood lactate (BL) was also recorded at half-time and post-match and it reported as higher at the half-time than post-match, respectively 2.0 vs. 1.5 and 2.33 vs.1.8 $mmol.l^{-1}$ (Rebelo *et al.* 2011; Dixon 2014a). Rebelo *et al.* (2011) stated that the reduction of BL post-match was because the reduction of total distance of sprint and HIR in the end of the match. So, dropping total distance, heart rate, blood lactate in the end of the game could be indicative of fatigue.

In terms of the total distance covered of Futsal players and referees, the majority of studies (Dogramaci, Watsford and Murphu 2011; Barbero-Alvarez *et al.* 2008; Doğramacı and Watsford 2006) stated that Futsal players have covered 4.277, 4.313 and 4.284 km respectively. While, the only available study about the Futsal referees shows that Futsal referees have covered 5.9 km which is quite different from the Futsal players (Rebelo *et al.* 2011). Moreover, more research on Futsal referees is required: the rules were changed in 2010, which may impact on the style of the game and also there is little known about the physical demands and requirements of referees. As mentioned above Futsal players covered less total distance than referees (Rebelo *et al.* 2011; Doğramacı and Watsford 2006) Futsal players covered around 1 km cruising, however over time the amount of distance has been increased and it was observed in 2012 (Makaje *et al.* 2012) that cruising reached was 2.85 km. In addition to that Futsal players covered 0.1 km sprint in 2006 (Doğramacı and Watsford 2006) but the amount of sprinting rose in 2012 to 0.42 km (Makaje *et al*. 2012). This is due to the Futsal game getting faster than before and the physical demands of play increasing. Generally, the demands of Futsal players have increased (i.e. walking and jogging have decreased and cruising and sprinting have increased from 2006 to 2012) (Doğramacı and Watsford 2006; Makaje *et al.* 2012) as shown in Table 3.1. This may be related to the laws of the game changing (2010) and Futsal has developed tactically and technically. To sum up this, the demands of Futsal seem to have increased since the rule change (but this has only been studied in players), notably, the 2010 rule change requires both referees (referee and second referee) to be positioned about 5 m from the location of kick-ins (which was not previously required) and this likely contributes to the increased demands placed on referees.

Table 3.1: Motion analysis distance of Futsal referees, Futsal players and football assistant referees (ARs)

		Walking	Jogging	LIR	MIR	HIR	Sprint	Backwards	Sideways	Total
(Rebelo *et al.* 2011) Futsal Refs		2,674 ± 488	489 ± 195	719 ± 305	618 ± 205	259 ± 99	87 ± 82	135 ± 128	911 ± 461	5,892 ± 564 m
(Dogramaci, Watsford and Murphu 2011) Futsal players		635 ± 204	1521 ± 558	999 ± 332			106 ± 59.9	1022 ± 213		4284 ± 1033 m
(Doğramacı and Watsford 2006) Futsal players		134 ± 45.7	1340 ± 580	993 ± 330			106 ± 59.9	1008 ± 212		3582 ± 932 m
(Makaje *et al.* 2012) Futsal players	Elite	514±112	1302±671	1165±526	1050±355	636±248	422±186	-		5087±1104 m
	Amateur	551±127	1220±664	1019±573	896±381	534±276	308±203	-		4528±1248 m
(Barbero-Alvarez *et al.* 2012) ARs		1,610 ± 67	-	2,010 ± 221	1,410 ± 262	481 ± 100	97.2 ± 87	-		5,819 ± 381 m
(Krustrup, Mohr and Bangsbo 2002) ARs		3.08 ± 0.11	1.03 ± 0.06	0.80 ± 0.04	0.50 ± 0.03	0.34 ± 0.03	0.31 ± 0.04	1.22 ± 0.15		7.28 ± 0.17 km
(Mallo *et al.* 2009b) ARs		1368 ± 144	1608 ± 211	922 + 158		1047 ± 342		-		5752 ± 554 m

3.2. Physical demands:

Referees must be in a suitable physical condition to cover the necessary distance and maintain performance (e.g. ability to move at speed to an incident, or keep up with play to optimise viewing position and make decisions), which requires sufficient components of physical fitness. Capacity to perform these skills and components could be increased or decreased during the game (e.g. due to fatigue) and affect referees' performance. Total distance covered throughout a match gives an indication of the total demand (Rienzi et al. 2000) but activity profile provides more specific insight. The activity profile in football teams is dependent on the nature of the competition, and game, the playing position and could be impacted by the distance covered by the ball (Rienzi *et al.* 2000; Mallo *et al.* 2009b) and this could affect performance (Barbero-Alvarez *et al.* 2012). Such factors will of course also dictate the demands placed upon referees (i.e. in order to keep up with/follow play appropriately).

As it was mentioned above Futsal referees covered 5,892 m. Unlike Futsal, football referees (Refs) are reported to cover a total distance of 9 to 12 km per match (Table 3.2); however football assistant referees (AR) cover 5 to 7 km (Table 3.2). The most reasonable explanation for this observation is that football referees will cover the whole pitch; however football assistant referees only cover half of the pitch and remain on the touch lines. The demands of Futsal referees are more similar to ARs as Futsal referees run almost the same total distance as ARs, and dynamically the movements of Futsal referees are more similar to football assistant referees because positioning of both referees is on the touch lines and facing the pitch during the game. Futsal referees use different types of movements, such as forward, backward and sideways running, which are much more prevalent in Futsal, in order to choose a good position and gain an appropriate angle of view, and also to minimise the errors (Verheijen *et al.* 1999).

Consideration of the level of competition (or high vs lower level leagues) has been proposed as a factor that may explain some of the observed differences in football referees (Bangsbo, Iaia and Krustrup 2008). In addition, it has also been shown by Ekblom (1986) that high-level football players (professional) cover more distance than those at lower levels. Additionally, the rank of division has been shown to be associated with the movement pattern of football referees (Castagna, Abt and D'ottavio 2004). It has been reported that referees required to have high performance and capabilities to officiate the higher levels of competition (when comparing European, Premiership, and

Championship matches) covered more total distance than lower level (11.991, 11.602, and 11.308 km, respectively) (Di Salvo, Carmont and Maffulli 2011); and football players and referees at the higher level tournaments covered a greater total distance than the lower level (Gabbet and Mulvey 2008; Krustrup *et al.* 2009). However, Castagna, Abt and D'Ottavio (2004) found that national football referees covered more distance than international referees. These variations could be due to the phase of the competition, the style of playing and the work-rate capacity of players (Ben Abdelkrim, El Fazaa and El Ati 2007) which may impact on the referee's movement pattern, or the tempo of the game (alternatively, the experience and ability to predict play and chose better starting positions may also influence the total distance covered, which could be a potential explanation for the higher level being associated with lower distance in the latter study). Whenever the tournament reaches the final round, the tempo of the game may also increase; thus, the referees are required to be more active. For example, the referee's movement in a basketball match developed throughout competition phases from the first round (4.02 km) to the semi-final (4.97 km) to the final (6.17 km) (Borin *et al.* 2013).

Fitter referees may have better capacity to maintain intensity and meet the physical demands (e.g. keep up with play effectively) for the duration of the game (however, as mentioned above, this may also be related to other factors like experience and positioning). So, fitness is an important factor that should not be neglected, particularly when referees need to make important decisions. It was observed in one study with Italian referees that referees who were closer to the situation (ball) did cover more total distance during the game than referees whom far from the action area, and also being closer to the action was associated with more correct decisions and minimise the possibility of referees' errors (Castagna and D'ottavio 2001). To some extent, positioning might be affected by referee experience and game awareness but the physical capacity (i.e. physical fitness) is key to allowing them to get into the optimum position and/or to keep up with play: in order to make correct decisions (Harley, Tozer and Doust 2001). Furthermore, it was found in the results of Krustrup et al. (2009) that physical demand is high in the professional (international) matches for referees and as a consequence it is crucial to assess referees' fitness levels.

Fitness and match demands:

Fitness capacity for referees may be defined as the ability to maintain movement and keep up with play (in line with the demands of the match) by changing activities from walking to high intensity running and positioning themselves to achieve the right angle during match in order to observe players' behaviours. Fitness status aids referees to keep up with play and thus it aids referees to avoid , or resist, the effects of fatigue (Ager 2015). The activity profile during matches can be an indicator of referee performance in relation to the physiological demands of the game (for example a reduction in distance, or higher intensity activities during a match may indicate fatigue). Therefore, referees Department assess their referees' fitness as part of the selection process. In recent years, a number of field and laboratory tests has been used in football referees to evaluate referees' fitness and it has been an increasing interest in the relationship between motion analysis and a battery of fitness tests for football referees (Krustrup and Bangsbo 2001; Castagna and D'ottavio 2001; Castagna, Abt and D'ottavio 2002; Castagna, Abt and D'Ottavio 2005; Mallo *et al.* 2007) and Futsal referees (Rebelo et al. 2011). The rationale for these tests is that they relate to the demands of the game or give an indication of a referee's ability to perform during matches (i.e. keep up with play and maintain this for the duration of a match). In football Castagna, Abt and D'Ottavio (2005) examined two fitness tests (the Yo-Yo intermittent recovery test and the 12-minute run test) to determine which test is more relevant to referees and suggested that the Yo-Yo was more useful than the 12-minute run to assess referee-specific endurance performance ability. Several studies focused on this relationship and indicated that the Yo-Yo intermittent recovery test is a good test and could be utilized to assess referees' match-specific fitness (Krustrup and Bangsbo 2001). More generic measures of 'aerobic' capacity/fitness are not useless as general fitness is still an important component (e.g. the 12-minute Cooper run was shown to be a reasonable predictor of referees' match activity profile/performance (Castagna, Abt and D'Ottavio 2005), but they lack the specificity to many of the activity demands of intermittent sports. Castagna and D'Ottavio (2001) also noted that there was a positive association between VO_2max and movement patterns (total distance) in referees. However, the findings of Mallo *et al.* (2007) indicated that the old FIFA fitness tests were not ideal (lack sports-specificity). Unlike football, Futsal referees have their own fitness test which is set by FIFA. Recently (June 2016) FIFA have updated and replaced the traditional fitness testing battery to the newer fitness tests which includes a modified Yo-Yo Intermittent Endurance Test – Level 2 (also named the

Assistant Referee Intermittent Endurance Test: ARIET). The traditional testing battery, in particular the 1000 m endurance test was criticised since, although it may give some indication of aerobic fitness capacity, it lacks sport-specificity. Rebelo *et al.* (2011) and Dixon (2014b) pointed out that the Yo-Yo IET-2 is a more appropriate test for Futsal referees and has a better relationship with match activity.

Fitness tests are frequently used in sports as a tool to choose the best athletes for competition based on physiological condition and fitness. The rationale of referee fitness tests is primarily to assess their physical capacity, and secondly (for many associations) (FIFA 2016b) to assist with the identification and nomination of the best, or most appropriate, referees. That is, in some cases to classify them by fitness test results, when they are equal in technique and knowledge of the rules because a referee with good physical capacity will be able to keep up with play better than a referee with lower fitness capacity. For match officials, such tests are used to ensure that they meet minimum physical requirements deemed necessary to allow them to discharge their duties effectively during competition (e.g. keep up with play to allow good position to view incidents etc. in order to make correct decisions). For many team sports, such as football, basketball, handball, beach soccer and Futsal, referees must pass a battery of such fitness tests before they can be appointed to officiate in competitive matches, in accordance with their national or international associations. There are several studies (Castagna, Abt and D'Ottavio 2002; Harley, Banks and Doust 2002; Krustrup and Bangsbo 2001) that have investigated fitness tests for football referees in relation to physiological demands of their role and for Futsal referees (Rebelo et al. 2011; Dixon 2014b), so it is necessary to obtain data and information about new fitness test and referees' performance.

FIFA Fitness tests for referees:

Recently FIFA has changed the fitness test of referees in all their games (football, Futsal and Beach Soccer) (FIFA 2016b), thus it is important to investigate relationships between the new fitness tests and referees' match performance.

The fitness testing battery consists of three tests:

FIFA Fitness test for Futsal referees and Beach soccer:

Introduction: The official fitness test for futsal and beach soccer referees consists of three tests:

Test 1, Speed

Test 2, CODA

Test 3, ARIET

The time in between the end of Test 1 and the start of Test 2 should be 2 to 4 minutes. The time between the end of Test 2 and the start of Test 3 should be 6 to 8 minutes. Testing should be performed on a Futsal pitch or a similar surface.

Test 1, Speed, measures the referee's time to cover 20 metres (Figure 3.1).

The 'start' gate must be placed at 0 m and the 'finish' gate at 20 m. The 'start line' must be marked out 1.5 m before the 'start' gate. Referees should line up at the start with their front foot touching the 'start line'. Once the test leader signals that the electronic timing gates are set, the referee is free to start. Referees should receive a maximum of 90 seconds recovery between each of the 2 × 20 m sprints. During their recovery, referees must walk back to the start. If a referee fails one trial out of the two, they should be given a third trial immediately after the second trial. If they fail two trials out of three, the match official has failed the test (FIFA 2016b).

International and category 1 referees are required to complete the test in 3.30 seconds or quicker; lower categories in 3.40 seconds or quicker (FIFA 2016b).

Figure 3.1: Speed Test (FIFA 2016b)

Test 2, CODA, assesses the referee's ability to change direction (Figure 3.2):

Cones must be set out as illustrated in the diagram below. The distance between A and B is 2 metres. The distance between B and C is 8 metres. Only one timing gate is required for the CODA (A). The 'start line' must be marked out 0.5 m before the timing gate (A). Referees should line up at the start with their front foot touching the 'start line'. Once the test leader signals that the electronic timing gates are set, the referee is free to start. The referees sprint 10 m forward (A to C), 8 m sideways left (C to B), 8 m sideways right (B to C) and 10 m forward (C to A). If a referee falls or trips, they should be given an additional trial (FIFA 2016b).

International and category 1 must complete the test in 10 .0 seconds or faster; lower categories in 10.1 seconds or faster (FIFA 2016b).

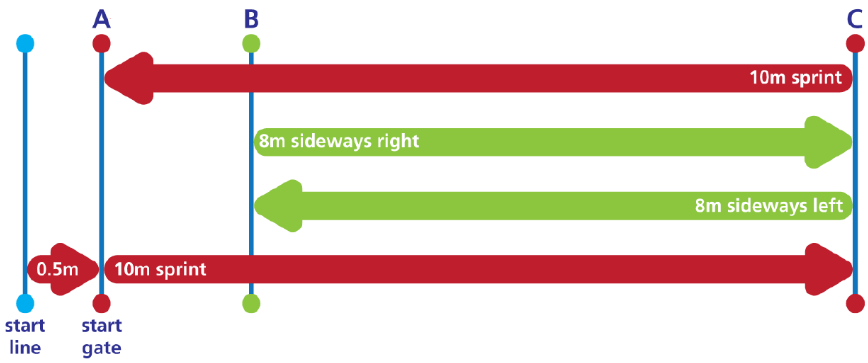


Figure 3.2: CODA Test (FIFA 2016b)

Test 3, ARIET (Assistant Referee Intermittent Endurance Test), measures the referee's capacity to perform repeated forwards and sideways running bouts over a prolonged period (Figure 3.3). The referee must complete the following sequence in accordance with the pace dictated by the audio signal.

Cones must be set out as illustrated in the diagram below. The distance between A and B is 2.5 metres. The distance between B and C is 12.5 metres. The distance between B and D is 20 metres. Referees must start from a standing position. They must complete the following sequence in accordance with the pace dictated by the audio file (FIFA 2016b).

a. run 20 m forwards (B-D), turn and run 20 m forwards (D-B)

b. walk 2.5 m (B-A), turn and walk 2.5 m (A-B)

c. run sideways 12.5 m (B-C), and run sideways facing the same side 12.5 m (C-B)

d. walk 2.5 m (B-A), turn and walk 2.5 m (A-B)

The audio signal dictates the pace of the runs and the length of each recovery period. Referees must keep pace with the audio signal until they have reached the required level. The starting position requires the referees to be standing still with their front foot on the line (B). Referees must place a foot on the turning lines (C & D). If a referee fails to place a foot on the lines B, C or D on time, they should receive a clear warning. If a referee fails to arrive on time on a second occasion, they should be pulled from the test by the test leader and the test is ended and performance recorded (FIFA 2016b).

International and category 1 referees are required to achieve level 15.5-3 / 1,275 metres; lower categories are required to achieve level 15-3 / 1,170 metres (FIFA 2016b).

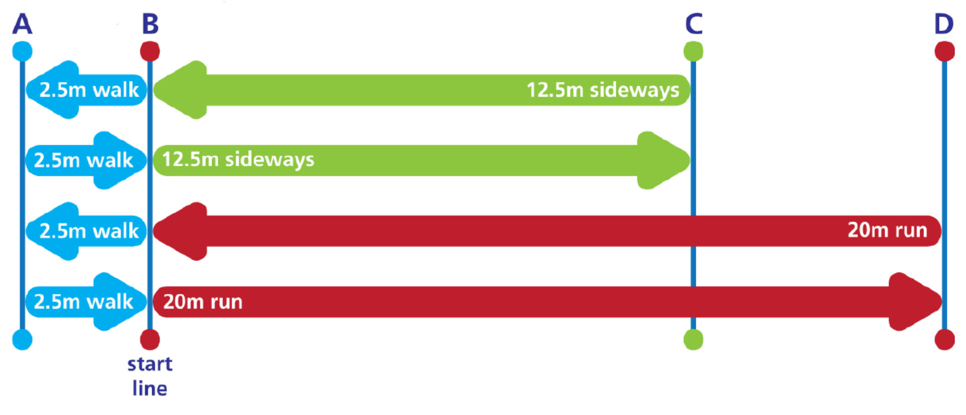


Figure 3.3: ARIET Test (FIFA 2016b)

FIFA Fitness test for football referees:

It consists of two tests;

Test 1, Repeated Sprint Ability (RSA), measures the referee's ability to perform repeated sprints over 40 m (Figure 3.4)

Test 2, Interval Test, evaluates the referee's capacity to perform a series of high-speed runs over 75 m interspersed with 25 m walking intervals (Figure 3.5)

Figure 3.4: Repeated Sprint Ability (RSA) (FIFA 2016b)

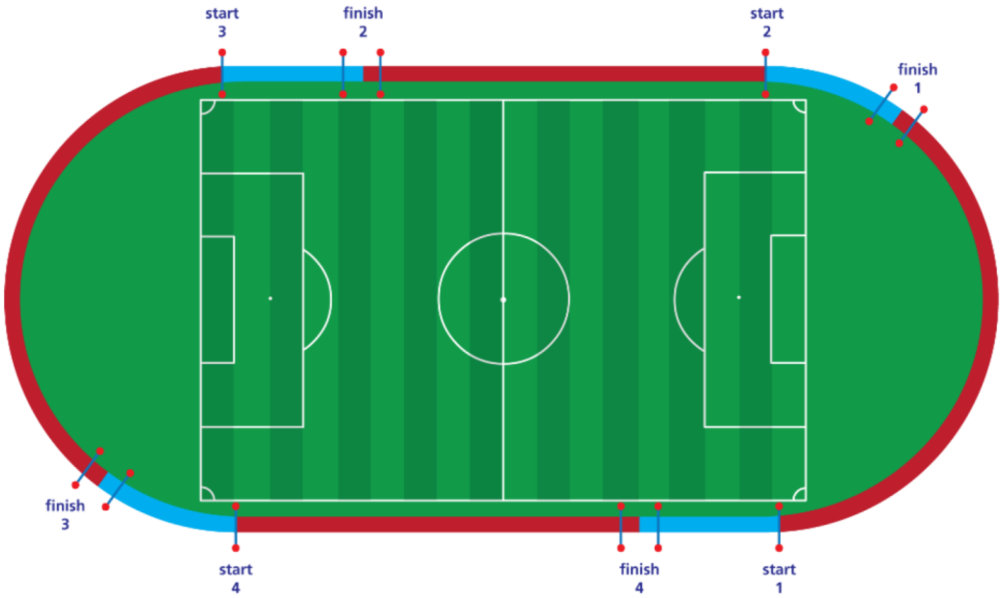


Figure 3.5: Interval Test (FIFA 2016b)

FIFA Fitness test for football assistant referees:

The official fitness test for football assistant referees consists of three tests.

Test 1, CODA, assesses the assistant referee's ability to change direction (Figure 3.2)

Test 2, Repeated Sprint Ability (RSA), measures the assistant referee's ability to perform repeated sprints over 30 m (Figure 3.6)

Test 3, Interval Test, evaluates the assistant referee's capacity to perform a series of high-speed runs over 75 m interspersed with 25 m walking intervals (Figure 3.5)

Figure 3.6: Repeated Sprint Ability (RSA) (FIFA 2016b)

Motion analysis (with clock-time and match-time):

Motion analysis has been used widely over the last two decades to measure movement patterns of athletes in individual and intermittent sports. To date various methods have been developed and introduced to measure athlete's movement patterns during the match. In sports with a stop clock rule (whereby the match timer is paused during any stoppages in play) it is important to consider separate analyses for total match duration (match-time) and active match duration (i.e. only when the ball is in play and active: clock-time). So, it is important to consider estimating athletes (referees and players) when the ball is in and out of play and recently a study on rugby (Gabbett et al. 2014) has pointed out that research is needed to see physical demands differences when the ball is in and out of play in team sports. Clock-time includes the time (from kick-off until half-time, then from half-time kick-off until full-time) (Doğramacı and Watsford 2006, p.75) with the exception of when the ball goes out or the match is stopped by one of the referees. Rebelo *et al.* (2011) measured Futsal referees throughout the whole the match, regardless of whether the ball was in or out of play (i.e. match-time). According to law 7 (FIFA 2014), the duration of the Futsal match consists of "two equal periods of 20 minutes" and 40 minutes in total but this applies to clock-time when the ball is in play and excludes times when the ball is out of play a accordance law 9 (FIFA 2014, p. 36). However, in Futsal the time must be stopped during stoppages. Dogramaci, Watsford and Murphu (2011) point out that Futsal match duration typically lasts approximately 80 minutes in total. Moreover, Rebelo *et al.* (2011) and Dixon (2014a) also reported Futsal match duration of just over 80 minutes and Doğramacı and Watsford (2006) reported that the total Futsal match lasts more than 70 min. Therefore, it is clear that large differences exist between match time and clock time and presumably the activity demands differ also. It has been observed that football referees tend to cover greater total distance than Futsal referees (see Tables 3.1 and 3.2). Also football assistant referees cover slightly more than Futsal referees according to Rebelo *et al.* (2011).

This great difference between football referees and assistance referees could be because of the duration of the periods, the field of play and the running style of referees. Nevertheless, according to the team sports studies, Futsal referees covered more total distance than other referees (except football referees). The majorities of studies (Catterall *et al.* 1993; Gray and Jenkins 2010; Costa *et al.* 2013; Krustrup and Bangsbo 2001; Castagna, Abt and D'ottavio 2004) demonstrated that football referees and assistant referees' total distance ranged from 9 km to 13 km (Table 3.2). Conversely, Futsal referees cover 5.9 km, but there has been only one previous study assessing this specifically in Futsal referees (Rebelo *et al.* 2011). However, this figure may not reflect the exact total distance of Futsal referees since 2010 as the Futsal laws have changed. Additionally, the research of Castagna, Abt and D'ottavio (2004) showed that the rank or division can have an effect on the movement pattern of football referees, for instance higher level referees cover more distance due to greater match demands that than lower levels. Moreover, the paper of Di Salvo, Carmont and Maffulli (2011) report that the top levels of physical condition is of key importance for high level officials. The study of Gabbet and Mulvey (2008) revealed that athletes at the higher tournaments covered a greater total distance (10.9 vs. 10.3 km) than the lower level. This inconsistent in total distance covered could be due to level of tournament, team's tactical approach, and physical ability of players (Ben Abdelkrim, El Fazaa and El Ati 2007). Whenever the tournament reaches the final round, the tempo of the game may also increase.

A number of studies have also reported a decrease in distance covered in the 2nd (compared to 1st) half of the match. The reasons for this could be related to fatigue of players (change in game tempo) and/or referees. Mallo *et al.* (2008) have indicated that increased fatigue of players may change the velocity of the game, which is in line with Weston *et al.* (2006), Weston *et al.* (2011) and Da Silva, Fernandes and Fernandez (2008) have suggested that the reduction in referee distance covered in the 2nd half it is a consequence of a slower tempo of play or reduced distance/energy expenditure by players. However, Krustrup *et al.* (2009) reported that it could be also be related to the referee's fitness (e.g. they may not 'keep up' with play as well in the second half).

Table 3.2: Total distance covered by Football Referees (Refs) and Assistant Referees (ARs).

	Reference	Distance (Mean ± SD) m/km
1	(Barbero-Alvarez *et al.* 2012)	10,197 ± 952 m (Refs) vs. **5,819 ± 381 m (ARs)**
2	(Weston, Drust and Gregson 2011)	11,280 ± 738 m (Refs)
3	(Weston, Drust, *et al.* 2011)	11,770 ± 808 m (Refs)
4	(Da Silva, Fernandes and Fernandez 2008)	9155.4 ± 70.3 m (Refs)
5	(Weston *et al.* 2010)	11,534 ± 748 m (Refs)
6	(Krustrup *et al.* 2009)	10.27 ± 0.90 km (Refs) vs. **6.76 ± 0.83 km (ARs)**
7	(Mallo *et al.* 2009b)	**5,752 ± 554 m (ARs)**
8	(Mascarenhas *et al.* 2009)	10.32 ± 4.86 m (Refs)
9	(Mallo *et al.* 2008)	**6,137 ± 539 m (ARs)**
10	(Weston *et al.* 2007)	11,622 ± 739 m (Refs)
11	(Mallo *et al.* 2007)	11,059 m (Refs)
12	(Krustrup, Mohr and Bangsbo 2002)	**7.28 ± 0.17 km (ARs)**
13	(D'ottavio and Castagna 2001a)	11,469 ± 983 m (Refs)
14	(D'ottavio and Castagna 2001b)	11,376 ± 1604 m (Refs)
15	(Castagna and D'ottavio 2001)	11,584 ± 1,017 m (Refs)
16	(Krustrup and Bangsbo 2001)	10.07 ± 0.13 km (Refs)
17	(Di Salvo, Carmont and Maffulli 2011)	European/Premiership/Championship 11.308, 11.602, and 11.991 km (Refs)
18	(Castagna, Abt and D'ottavio 2004)	National and international Refs 12,956 ± 548 m and 11,218 ± 1,056 m (Refs)
19	(De Oliveira *et al.* 2008)	9,351 ± 1,022 m (Refs)

3.3 Physiological responses:

Physiological responses can give a useful insight into the demands of a particular sport. Measurement of physiological responses of athletes can be undertaken in the laboratory or in field settings (e.g. during a match) depending on the measures required and equipment needed. There are many physiological parameters which give an indication of the intensity of exercise that may be utilized during (or immediately after) actual match, such as heart rate (HR), rating of perceived exertion (RPE) and blood lactate. Physiological responses in referees have been examined in several studies both during exercise in field settings and in laboratory-based studies (Krustrup and Bangsbo

2001; Krustrup, Mohr and Bangsbo 2002; Weston *et al.* 2006; Castagna, Abt and D'ottavio 2007; Mallo *et al.* 2009b; Barbero-Alvarez *et al.* 2012), but there are only a few studies specifically in Futsal referees (Rebelo et al. 2011; Dixon 2014a).

Heart rate (HR):

Heart Rate is commonly used as an indicator of exercise intensity. Numerous studies of referees (in football and Futsal) have used HR monitoring throughout matches to give an indication of exercise intensity and physiological demands during the match since it is very non-invasive. It does not interfere with the referee in undertaking their duties at all. In the football game, there are similarities and differences among scientists for reporting HR for referees. Weston and Brewer (2002) reported the mean heart rate of 153 bpm in football referees, however one decade later Costa *et al.* (2013) reported an average HR for referees of 160–165 bpm. This differences could be because of the demands of the game changed between these periods although Krustrup and Bangsbo (2001) reported a mean HR of 162 bpm during the match. Additionally, D'Ottavio and Castagna (2001) report that mean heart rate during the match is 163 bpm, and Catterall *et al.* (1993) reported 165 bpm. Here, it is noteworthy that the majority of studies (Johnston and McNaughton 1994; Krustrup and Bangsbo 2001; D'ottavio and Castagna 2001b; Reilly and Gregson 2006; Costa *et al.* 2013) on football referees reported mean heart rate between 160 - 166 bpm. In regards to 1st and 2nd halves, there was no difference in heart rate between both halves for football referees (Krustrup and Bangsbo 2001; Catterall *et al.* 1993), however in other literature (Weston and Brewer 2002; Krustrup, Mohr and Bangsbo 2002; Mallo *et al.* 2010) it was observed that there was significant decreases in the second half. Reilly and Gregson (2006) highlighted that whether or not HR decreases may depend on the level of competition.

In relation to football assistant referees' mean heart rate during a match was reported as 140 bpm (Mallo *et al.*, 2009), which agreed with Reilly and Gregson (2006). Krustrup, Mohr and Bangsbo (2002) observed slightly lower results than those other studies, which was 137 bpm. Nevertheless, the findings of Krustrup *et al.* (2009) found significant differences compared to other studies in which the average HR of assistant referees was 161 bpm. The difference between football referees and assistant referees may be owing to the fact that the football referee has two assistant referees and each of them has responsibility for half of the pitch, so they run less than the referee. Besides, assistant referees run only on the touch line, which is different from referees' running style and movement patterns.

Blood Lactate (BL):

Blood lactate (BL) concentration is another physiological response commonly used as an indicator of the intensity of exercise. According to literature on football referees, generally BL has been taken at three times; pre-, half-time and post-match to see how workload was during the 1st or 2nd half. Numerous studies have examined BL for referees at half-time and post-match, in the study of Krustrup *et al.* (2009) there was no significant difference in BL at half-time and post-match, respectively 3.4 vs. 4.6 mmol.l^{-1} but it was observed that it tended to be higher at post-match. Additionally, the findings of Krustrup and Bangsbo (2001) also reported that there was no difference at half-time and post-match, respectively 4.8 vs. 5.1 mmol.l^{-1}. According to the available literature on football assistant referees (Krustrup, Mohr and Bangsbo 2002; Krustrup *et al.* 2009), there were also no differences found in BL at half-time and post-match, respectively 4.7 vs. 4.8 and 2.8 ± 1.4 vs. 2.8 ± 2.6 mmol.l^{-1}. It has been observed that BL for football referees reached 14 mmol.l^{-1} post-match (Krustrup and Bangsbo 2001), nevertheless MacMahon *et al.* (2014) stated that due to inconsistency of BL (and frequent fluctuations during intermittent activities) it might not be the best index for referees' physical condition. Indeed, blood lactate may increase quickly or decrease depending on intensity of exercise, so a major limitation with BL measurements is that it can only be collected pre, half-time and post-match in real competitions. Unlike football, based on the two research studies available on Futsal referees, BL was lower at half-time compared to post-match, as reported by Rebelo *et al.(*2011) (2.0 ± 0.8 vs. 1.5 ± 0.5 mmol.l^{-1}) and (Dixon 2014c) (2.33 vs. 1.74 mmol.l^{-1}). However, these measures may only give an indication of the period shortly before the sample was taken and are therefore not necessarily a good representation of the whole half/match *per se*.

Rating of perceived exertion (RPE):

Rating of perceived exertion (RPE) is used as an effective tool to monitor physical activity load in team sports for athletes (players and referees) (Foster et al. 2001; Weston et al. 2010; Impellizzeri et al. 2004; Foster 1998). However, the traditional RPE scale (e.g. Borg, 1998) is designed to capture the perception of exertion immediately in the 'here and now' (i.e. at the instant of collection during exercise) and will likely vary significantly at different times during intermittent exercise. However, the session RPE method of Foster *et al.* (2001) is designed so that athletes express their exertion post-exercise within 30 min but give a single, global rating that reflects the overall exercise session or task (i.e. the average of the whole match, or half). This is more suited to quantify overall/average perceived exertion of a whole match where it is impossible to ask athletes their RPE during a real-life setting, for instance it is impractical to ask referees for perceived exertion at regular/periodic intervals during the match. According to literature (Impellizzeri *et al.* 2004; Herman *et al.* 2006; Wallace, Slattery and Coutts 2009; Manzi *et al.* 2010; Moreira *et al.* 2012; Costa *et al.* 2013) the session-RPE (10 scale) is a valid and reliable tool to estimate exercise intensity and perceived exertion in team/intermittent sports.

In light of the literature data for the average RPE in team sports, Milanez *et al.* (2011) found that the average RPE for Futsal players was 7.2 ± 1.1, which was quite high due to the high intensity nature of the Futsal game (Burns 2003). There is not any research on Futsal referees to estimate RPE. Unlike Futsal, there are several investigations on football referees, according to Costa *et al.* (2013), the session RPE scores of football referees was 5.5 to 8.0 which is ("hard" to "very hard"), and Weston *et al.* (2006) also reported similar findings in the Football League with an average of 6.9; however, this study argued that the mean match RPE scores for football League was less than the Premier League referees with figure of 7.8. In the field of refereeing, Weston *et al.* (2006) revealed a correlation between HR and RPE scores, and also Costa *et al.* (2013) indicated that the HR and session RPE methods are two indicators that represent the work-rate within matches well. Foster (1998) stated that the session RPE associates with the topical indicator of exercise intensity, for instance HR and BL. This means that it could be acceptable to measure the session RPE only in circumstances when other measures are not convenient or possible, such as during official competitions. The session RPE is also associated with blood lactate responses and oxygen uptake (VO_2) responses, further demonstrating its value as an indicator or exercise intensity. Additionally, Costa *et al.* (2013) stated that the session RPE offers related information to the other physiological demands throughout the matches. Moreover, Wallace, Slattery and Coutts (2009) reinforce that the session RPE has a strong relationship with physiological measures of exercise intensity such as, VO_2, blood lactate and HR.

3.4. Cognitive performance and decision-making:

Assessing cognitive function is of wide interest in the field of sport science and there are many different types of cognitive tests that are employed, such as Stroop tasks, the psychomotor vigilance task (PVT) and AX-continuous performance test (AX-CPT). The Stroop test has good test-retest reliability (e.g. intraclass correlation coefficients, ICC, of 0.71 for the congruent Stroop task and 0.79 for the incongruent Stroop task) (Strauss *et al*. 2005) and have been used to evaluate football referees' performance (Badin *et al*. 2016). AX-CPT is also another reliable test for assessing cognitive performance (Halperin et al. 1991), with reliability coefficients between 0.70 – 0.74 (Cooper *et al.* 2017; Strauss *et al.* 2014). However, the PVT is the most common/widely used in sport and it measures reaction time and the ability to sustain attention (Dinges and Powell 1985; Dinges *et al*. 1987; Loh *et al.* 2004) and it has high reliability with ICCs above 0.8 for all parameters measured within this test (Dorrian, Rogers and Dinges 2005). The 10-min PVT is an extensively recognised measure of neurobehavioral performance and cognitive functioning (Lamond, Dawson and Roach 2005; Seicean et al. 2011; Jewett *et al.* 1999), that is extremely suitable for laboratory studies (Dorrian, Rogers and Dinges 2005; Dinges *et al.* 1997; Dinges and Powell 1985; Tilley and Wilkinson 1984). However because of portable nature of the PVT and ease of administration, valuable practical insight can be gained from using the PVT in field-based settings.

Decision-making is one of the main significant components in which athletes (players and referees) need to decide on or respond to a stimulus, often with little time to deliberate. As such, decision-making is an important performance component for referees, who are required and expected to make important decisions to implement the rules of the game effectively to officiate the match. A study by Willams and Ford (2013) defined decision-making as the capacity to utilize the information from the current incident and using their own knowledge to judge it (cited by Causer and Ford 2014, p. 385). During a football game the referee has responsibility and authorisation for taking any decision that is related to the game with cooperation from assistant referees. In Futsal there are two referees and they are responsible for implementing the rules to control players' behaviours. Decision-making is one of the higher priority components of referees and the outcome of the game is associated with their performance and correct decision-making. Refereeing is not an easy job as they are required to deal with many aspects of stress, such as players, coaches (benches), media and spectators, and when they may face lots of external pressure from the above mentioned ‘stakeholders’ who may try to influence their decisions and thus change the outcome of the game (Elsworthy, Burke and Dascombe 2016; Paradis, Larkin and O’Connor 2016). It was reported that referees with more experience can cope more effectively with stress and pressure (Dohmen 2008; Janelle, Singer and Williams 1992).

Mechanism of decision-making:

Bless *et al.* (2004) have made a framework of decision task (cited by Plessner and Haar 2006, p. 557 & 558) and it has detailed in Figure 3.7. The framework of analysing decision-making process in refereeing is as follows; at first, the situation has been seen it as a “stimulus has to be perceived (e.g., the referee needs to attend to the tackle situation). Next, the perceived stimulus is encoded and given meaning (e.g., it is categorized as a forbidden attack on the opponent). This second step relies heavily on prior knowledge (e.g., the referee must retrieve the decision criteria for forbidden tackles from memory). In addition, the encoded episode will be stored (automatically) in memory and may influence future judgments, just as retrieved episodic memories influence current processing (e.g., the referee remembers that the attacking player has been warned before). In a final step, the perceived and encoded information is put together with the retrieved memories and other information that is available or inferred, and is integrated into a judgment that is expressed as a decision (e.g., awarding a free-kick and sending the attacking player off)” (Plessner and Haar 2006). Besides the above points, referees’ experiences, the tempo of the match, fatigue and pressure may play a role to influence positively or negatively on decision-making.

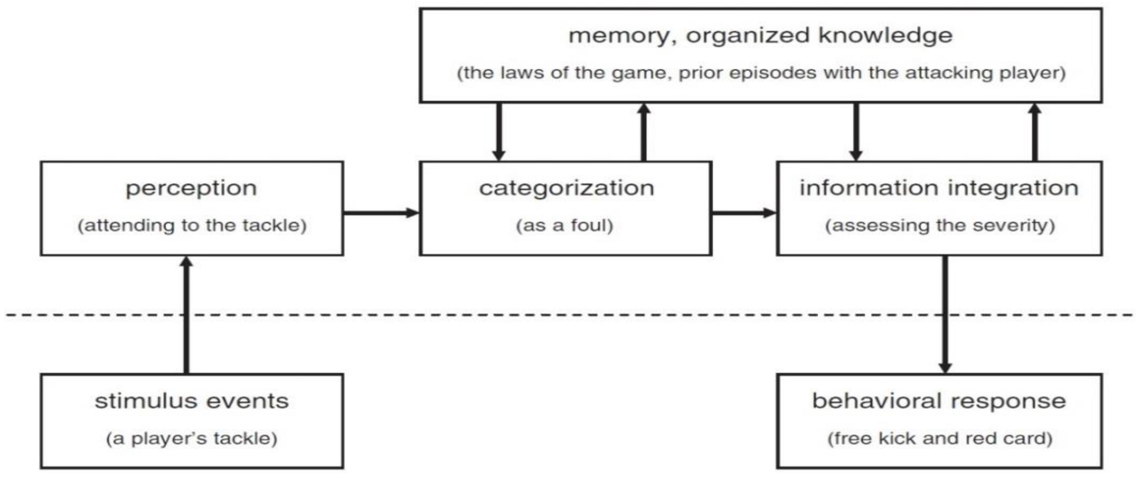


Figure 3.7: An example of a football referee’s decision-making process. Form Plessner and Haar (2006) (which is originally from Bless et al., 2004)

Decision-making of football referees has been investigated in different contexts, for instance examining referee positioning in relation to their decision-making during actual match (Harley, Tozer and Doust 2001; Catteeuw, Helsen, Gilis and Wagemans 2009; Catteeuw, Gilis, García-Aranda, *et al.* 2010; Oudejans *et al.* 2005; Mallo *et al.* 2012; Gilis *et al.* 2008), proportion of correct/incorrect decisions of football referees and assistant referees during actual matches (Van Meerbeek, Van Gool and Bollens 1987; Helsen and Bultynck 2004; Helsen, Gilis and Weston 2006; Oudejans et al. 2000; Oudejans et al. 2005; Elsworthy, Burke and Dascombe 2014; Catteeuw, Gilis, García-Aranda, et al. 2010) and using training programmes to improve and enhance decision-making (Brand, Plessner and Schweizer 2009; Schweizer *et al.* 2011; MacMahon *et al.* 2007; Catteeuw, Helsen, Gilis and Wagemans 2009; Put *et al.* 2013). It is difficult to investigate the factors that influence referees' decision-making during real matches, although some studies have used video analysis and expert panels to rate refereeing decision-making/performance afterwards (Brand, Plessner and Schweizer 2009; Schweizer *et al.* 2011; MacMahon *et al.* 2007; Catteeuw, Helsen, Gilis and Wagemans 2009; Put *et al.* 2013). This can be useful to examine relationships between referee fitness test performance and decision-making performance, or how the proportion of correct decisions change over a game (i.e. with fatigue), or explore other relationships with this aspect of referees' performance and decision-making. However, observing real matches is not an ideal model for a repeated measures crossover design to study, for example, how a particular condition or interventions influences performance as this requires a controlled and repeatable exercise. For this reason, laboratory studies that simulate the demands of a match in a controlled and reliable way may be advantageous. Numerous factors may influence this aspect of referee performance, for instance physical demands (e.g., distance coverage) and fatigue, psychological factors (e.g., concentration, coping with pressure, mental fatigue) the ability to manage players' behaviours (Slack et al. 2013; Samuel 2015). Although there are various studies that have examined referees' perceptual-cognitive performance (e.g. decision-making), there are currently no such studies with Futsal referees. Hence, more research investigating the cognitive processes related to decision-making are required (Weston *et al.* 2012; Taylor *et al.* 2014; Watkins *et al.* 2014; Paradis, Larkin and O'Connor 2016).

Decision-making and fatigue:

There is no doubt that the main role of referees, either in Futsal or football, is to implement the rules of the game correctly and this requires them to maintain full concentration over prolonged periods (~80 min match time) and make accurate decisions. Indeed, Helsen and Bultynck (2004) stated that decision-making is the most essential success element of refereeing. Therefore, referees play an important role in the game that can influence the final result/outcome. Considerable attention must be paid on mental fatigue which may influence referees' performance and decision-making and existing concurrent assessment of physical and mental fatigue is limited to evaluating referee's physical performance, especially since it is not easy to measure fatigue accurately, particularly mental fatigue which is often an overlooked element in the match by referees.

Mental fatigue is defined as a psychobiological state caused by prolonged periods of demanding cognitive activity and characterized by subjective feelings of "tiredness" and "lack of energy" (Marcora, Staiano and Manning 2009). Fatigue is an important condition that needs to be understood in order to minimise referees' errors, and it was indicated that impaired concentration is linked to fatigue in referees and thus leads to more incorrect decisions (Catteeuw, Gilis, Wagemans, *et al.* 2010b; Ager 2015). However, Mehta and Parasuraman (2013) stated that fatigue is not well known and is complex. It was stated that fatigue in referees' leads to reduced concentration and thus leads to incorrect decisions (Catteeuw, Gilis, Wagemans, *et al.* 2010b; Ager 2015), and reduction of referees' performance in the second half of match play could be due to fatigue (Catterall *et al.* 1993; Weston *et al.* 2006; Mallo *et al.* 2008; Weston, Batterham, *et al.* 2011).

In the literature, researchers have reported different explanations for the decline in referees' cognitive performance in the second half; fatigue leads to incorrect decisions (Krustrup, Mohr and Bangsbo 2002) and increases the likelihood of referees' making a mistake (Ager 2015). However, a study of Catteeuw, Gilis, Wagemans, et al. (2010a) reported that incorrect decisions by football assistant referees were not caused by fatigue, running intensity and the angle of referees' view, stating that the reason was due to ARs concentrating on "the second-last defender and not shifting gaze" appropriately. Thus examining the role of cognitive performance of referees is critical to extend our knowledge on decision-making and to see the potential to avoid or minimise the effects of fatigue on this. MacMahon et al. (2014) pointed out that future research is required to explore the relationship between physical responses and decision-making by investigating the direct effects of physical stress on decision-making accuracy, and more recently Paradis, Larkin and O'Connor (2016) recommended coaches of football referees should spend more time to improve decision-making and concentration/sustained attention in general. In addition, the finding of Helsen and Bultynck (2004) reported that utilising different types (similar match environment) of training programmes for referees, such as video test, is needed to optimise referees' experiences.

The link between physical demands and decision-making:

It is important to investigate the relationship between physical demands and decision-making in referees. It was mentioned above that football referees and assistant referees cover between 9 to 13 km and 5 to 7 km, respectively, during the game (Table 3.2) whereas Futsal referees cover approximately 6 km per match (Rebelo *et al.* 2011). It has also been shown that total distance declines in the 2^{nd} compared to 1^{st} half (Di Salvo, Carmont and Maffulli 2011). Reilly and Gregson (2006) indicated that it has not been completely proven that fatigue caused the reduction in total distance of referees in the second half and this reduction might be due to the "tempo of the game". In terms of high-intensity running (HIR), it was observed that football referees and assistant referees' HIR were reduced in the second half, especially in the end of the match and this could be due to appearance of fatigue (Krustrup and Bangsbo 2001; Di Salvo, Carmont and Maffulli 2011). In line with HIR and decision-making, there were reductions in total distance for jogging and HIR in the second half (Di Salvo, Carmont and Maffulli 2011), and a study of Oudejans *et al.* (2005) reported that referees' errors were seen when the referee is running or sprinting compared to walking and jogging.

Summary:

Futsal referees' activity profile and physiological responses have been examined by only the study of Rebelo et al. (2011) and their fitness test was investigated and suggested that the Yo-Yo IET-2 is an appropriate fitness test to Futsal referees but no study compared relationships between the FIFA fitness (Pre-July 2016), Yo-Yo IET-2 and physical demands during actual matches for Futsal referees. There is a lack of studies that examine referees' cognitive performance pre- and post-actual match, and possible effects of fatigue during the game. Football referees' performance has been suggested to decline in the second half and this could be because of accumulated fatigue. The referee has an important role in the game and insufficient performance may influence the outcome of the game.

3.5 Aims and outline of the thesis

The aim of this present thesis was to investigate physiological, physical and cognitive performance of referees in field and laboratory studies. The thesis will examine the following aims and hypotheses:

Chapter 3 - Study one:

***Title**: Analysis of activity patterns, physiological demands and decision-making performance of Elite Futsal referees during matches*

Aims and hypotheses: The aims of this study were to analyse the activity profile and physiological demands of Futsal refereeing, referee decision-making performance at different stages of the match (e.g. 1st vs 2nd half). Another aim was to explore relationships between physical fitness/performance on the FIFA fitness tests, activity profile and decision-making performance. It is hypothesised that since the rules changed in 2010 Futsal referees will now face increased demands (total distance and high-intensity activities). Performance will be decreased in the seconds half compared to the first. Performance will be correlated with fitness test performance, but the intermittent type test will have a stronger relationship than the less specific endurance test (1000 m run).

Chapter 4 - Study two:

Title: Does the Psychomotor Vigilance test (PVT) influence psychomotor performance in referees? A pilot study

Aims and hypotheses: The aim of this study was to determine whether undertaking a 10- min Psychomotor Vigilance test (PVT) before a match would influence referees' cognitive performance, especially decision-making. It is hypothesised that **undertaking the** 10 min PVT 1 h before performance will not influence Futsal referees' cognitive/decision-making performance.

Chapter 5 - Study three:

Title: The effect of a competitive match on Psychomotor Vigilance in Futsal Referees

Aims and hypotheses: The aim of the present study was to assess referees' performance on the Psychomotor Vigilance Test (PVT) before and after competitive Futsal matches. It was hypothesised that Referees' PVT performance would deteriorate post-match as a result of physical and/or mental fatigue induced by the match.

Chapter 6 - Study four:

Title: Effect of mental fatigue on cognitive function and physiological responses to exercise in referees

Aims and hypotheses: Since mental fatigue may influence both physical and cognitive performance, the aim of this study was to examine the effects of mental fatigue of physiological responses and cognitive performance (e.g. decision-making). It was hypothesised that mental fatigue would increase physiological demand and/or perceptual responses and impair cognitive performance and decision-making.

Chapter 4

Analysis of activity patterns, physiological demands and decision-making performance of Elite Futsal referees during matches

I. Abstract

Background: There is little research on Futsal referees, with only one previous study to date. However, the previous Futsal referees study was conducted before FIFA implemented new rules (2010), meaning it may no longer be as applicable to the demands of the game. The aims of this study were to examine Futsal referee match activity profile, decision-making performance, and whether these correlate with fitness test performance.

Methods:

Eighteen male elite referees from Iraq Futsal Premier League (IFPL) matches (mean ± SD: age 34.1 ± 3.2 years; height, 171.2 ± 5.3 cm; weight 72.0 ± 3.6 kg) participated in this study (time-motion analysis of 9 matches). Referees were monitored during the match by video capture for motion analysis; heart rate was recorded throughout the match; lactate samples collected at rest (pre-match), half-time and post-match and session RPE for the first and second half expressed. In addition, ten of the referees undertook the FIFA Fitness tests (8 days before the match) and the Yo-Yo IET-2 (3 days before the match).

Result: Total distance covered (5943.6 ± 414.7 m: 3374.0 m ball in play) low-, moderate-, high-intensity and sideways running distances were similar to previous research; walking (1741.4 ± 225.1 m) was lower; sprinting (149.0 ± 59.2 m), jogging (754.9 ± 162.5 m) and backwards distances (654.7 ± 149.3 m) were higher. Total distance (3093.5 m vs. 2850.1 m) and average heart rate were higher ($p < 0.05$) in the first compared to second half but lactate and session RPE were similar. The proportion of correct decisions decreased in the second half (1^{st} 91.1 ± 14.9% correct vs 2^{nd} 73.3 ± 17.4%, $p = 0.002$). No correlations were evident between FIFA fitness tests and activity profile but Yo-Yo IET-2 performance and total distance (clock time) were correlated ($r = 0.720$, $p = 0.019$).

Conclusion: Activity pattern differences compared to previous research could reflect the FIFA rule change (2010) and/or different study populations. Decreases in the 2^{nd} half may be related to fatigue (physical and mental) in the latter stages of the match. Traditional FIFA tests seem less appropriate than intermittent (Yo-Yo IET-2) tests for assessing Futsal referee-specific fitness.

II. Introduction

Futsal is an indoor sport, characterized as an intermittent sport played between two competing teams of five players per team. It is officiated by two referees whom are required to stay outside of the pitch parallel to the touch line (FIFA 2014), and implement the Futsal laws of the game. They move up and down the touch lines to keep up with play and also to keep the other referee within their field of vision. There are various studies of physiological profiling for Futsal players (Castagna *et al.* 2009; Barbero-Alvarez *et al.* 2008; Doğramacı and Watsford 2006), however, there is little research on Futsal referees, with only one study to date (Rebelo *et al.* 2011) but this study was conducted before FIFA implemented new rules (2010). The new rules require Futsal referees (referee and second referee) to take up a position about 5 m from the location of kick-ins (which was not required previously). This requires more total distance and a different overall activity profile in order to take up these positions throughout the whole match. As such, the study conducted before the rule change may no longer be as applicable to the demands of the game. No studies have been conducted since the rule change, but the rule change may have influenced the demand on referees and, hence, their activity profile. For instance when the ball goes out of play referees must now move to that location (e.g. where the kick-in or corner kick is to be taken: about 5 m from the point of taking) (FIFA 2014, pp. 100 & 111).

Referees are expected to have a sufficient level of fitness to keep up with the game, therefore all national associations and confederations undertake and implement the FIFA fitness tests of referees before starting leagues/tournaments as part of the referee selection process. For match officials, such tests are used to ensure that they meet the minimum physical requirements deemed necessary to allow them to discharge their duties effectively during competition (e.g. keep up with play to allow good positioning to view incidents).

The fitness test for Futsal referees has recently changed (June 2016) from the traditional testing battery of a 1000 m run, 40 m sprint and 80 m agility tests (FIFA 2010) to the new fitness test (FIFA 2016b), which includes an intermittent test based on the Yo-Yo IET-2 test (modified Yo-Yo test, also named Assistant Referee Intermittent Endurance Test: ARIET). Previous research with Futsal referees has found significant relationships between performance on the Yo-Yo IET-2 and physiological responses (Dixon 2014b) and activity profile (Rebelo *et al.* 2011) during matches but not the traditional FIFA 1000 m endurance test.

Rebelo *et al.* (2011) observed a strong correlation ($r = 0.77$; $p < 0.05$) between High Intensity Running (HIR) in matches and the Yo-Yo IET-2 performance. Based on their findings, Rebelo *et al.* (2011) recommended that intermittent tests which involve changes of direction (such as the Yo-Yo IET-2) may have more relevance for Futsal referees than the (pre-2016) FIFA testing battery. More recently, Dixon (2014b) examined 58 officials (56 male and 2 female) at the FA National and Super Futsal League (who undertook the Yo-Yo IET-2, sprint (40 m) and agility (80 m) tests prior to the season). Dixon (2014b) also concluded that the Yo-Yo IET-2 is an appropriate test for Futsal referees, especially identifying differences in specific fitness between referees of different levels. Therefore the Yo-Yo IET-2 can be used to differentiate between different levels of futsal referees and it may be possible to use the test to identify those referees who show the fitness attributes for further development. Furthermore, Dixon (2014b) stated that further study is needed to understand the validity of the Yo-Yo IET-2 and its relationship with motion analysis of Futsal referees.

Several studies have investigated football referees' decisions (including consideration of positioning of referees in relation to the incident) (Harley, Tozer, and Doust 2001; Oudejans et al. 2005; Gilis, Helsen, Catteeuw, & Wagemans, 2008; Catteeuw et al., 2010; Mallo, Frutos, Juárez, & Navarro, 2012; Al Hazmi, 2016), and proportions of correct and incorrect decisions of football referees and assistant referees during matches (Van Meerbeek, Van Gool, and Bollens, 1987; Helsen and Bultynck 2004; Oudejans et al., 2000; Oudejans et al., 2005; Helsen, Gilis, and Weston, 2006; Elsworthy, Burke, and Dascombe, 2014; Catteeuw et al., 2010). However, there is no previous research that has examined decision-making for Futsal referees.

Hence, the aims of the current study were: 1) to examine the match activity profile of Futsal referees, 2) to examine decision-making performance, and 3) explore relationships between FIFA fitness tests, Yo-Yo IET-2 test performance and match activity.

III. Methods

Participations

Eighteen male elite referees in Iraq Futsal Premier League (IFPL) matches (mean ± SD: age 34.1 ± 3.2 years; height, 171.2 ± 5.3 cm; weight 72.0 ± 3.6 kg) volunteered to participate in this study. They all had over 5 years of experience as top level referees and were all officiating in IFPL 2013/2014. All participants were provided with information sheets and verbal explanations of the study procedures and possible risks and given a minimum of 24 hours prior to providing their written informed consent. Participants completed a health questionnaire (physical activity readiness questionnaire: PAR-Q) to assess their suitability to participate in the study. Referees were also informed of their ability to withdraw from the study at any time and for any reason. Ethical approval (Appendix 1) was granted from the School of Sport and Exercise Sciences Ethics Committee of the University of Kent, in line with the Declaration of Helsinki in advance of study commencement. All referees were required to undertake a series of Fitness tests as part of the Iraqi Football Association (IFA) requirements to officiate, which were conducted independently from this study but they also gave their consent for this data to be used for analysis in the present study (but records were only available for 10 referees for these tests: see further details below). These 10 referees were age 33.8 ± 5.0 years; height, 171.1 ± 6.0 cm; weight 71.9 ± 4.4 kg.

Study design

The present study recorded nine competitive matches with eighteen (2 per match) Futsal referees during IFPL 2013/2014. Referees were monitored during the match by video capture of the whole match for motion analysis; heart rate was recorded throughout the match; lactate samples collected at rest (pre-match), half-time and post-match and session RPE for the first and second half expressed. In addition, ten of the referees undertook two fitness tests with IFA: the FIFA Fitness tests were undertaken 8 days before the match and the Yo-Yo IET-2 was completed 3 days before the match.

Analysis of referees movement patterns and physiological responses to matches

Two GoPro Hero3 digital video cameras (GoPro, HERO3+Silver Edition, CHDHN-302, 2011) were used to record each match (each camera covering one side of the Futsal pitch). The cameras were placed on opposite sides of the pitch at the level of the halfway line, at a height of 3.5 m, and at a distance of 4.5 m from the touch line, (each camera covering one side of the Futsal pitch and 2 referees per match) to analyse movement patterns in competitive matches. The video data was analysed using Kinovea software (0.8.15) (www.kinovea.org). The software was calibrated using measured distances between markers on the pitch which were visible in the camera frame and speed was calculated from distance covered and duration of each activity. Based on Rebelo *et al.* (2011), Krustrup and Bangsbo (2001) and Bangsbo, Nørregaard and Thorsoe (1991) studies, movements of Futsal referees were classified into nine categories as follows: standing (0 $km.h^{-1}$), walking (up to 6 $km.h^{-1}$), jogging (up to 8 $km.h^{-1}$), low intensity running (LIR) (up to 12 $km.h^{-1}$), moderate intensity running (MIR) (up to 15 $km.h^{-1}$), high intensity running (HIR) (up to 18 $km.h^{-1}$), sprinting (above 18 $km.h^{-1}$), backwards (BW) and sideways (SW) movements.

The Futsal referees were analysed in two separate ways: 1) during clock-time, containing all movement activities performed from kick-off until the half-time interval, and from the second half kick-off until the end of play with the exception of when the ball goes out or play is stopped by one of the referees; 2) at match-time analysis level, which (in addition to above) also includes all movements when the ball is out of play; however, the half-time and time-outs were excluded from the analysis.

Reliability: All activity analyses in this study were conducted by the same operator (HA). However, in order to give an indication of method variability a different operator performed the same analysis on 1 match for comparison. The variation between operators ranged between -0.02% and 0.16% for distance covered (walking -0.14%, jogging 0.06%, LIR 0.05%, MIR 0.16%, HIR -0.12%, sprinting -0.14%, BW -0.02%, SW -0.02%, and total distance -0.02%). For activity duration variation between operators ranged between -0.06% to 0.03% (standing -0.01%, walking -0.05%, jogging -0.06%, LIR -0.05%, MIR -0.01%, HIR -0.01%, sprint -0.05%, BW 0.03%, SW 0.00% and total duration -0.02%).

Decision-making by observer panel assessment

Three independent expert Futsal qualified observers (two FA Futsal Assessors and one IFA Futsal Assessor) assessed decisions made by the referees by independently reviewing the footage from each match from the motion analysis recordings. Each observer independently watched and assessed the match videos and rated each refereeing decision (e.g. correct, incorrect, contentious) in line with the methods of Lovell (2014) so that a decision-making performance score (i.e. % correct decisions) could be calculated (if all 3 referees did not rate the decision the same the majority was taken: there was agreement between all 3 assessors on 71.5% of all ratings and at least two of the observers agreed on 99% of the ratings). Observers were allowed to watch the video/incident as many times as necessary for them to reach a decision (foul, no-foul or missed foul) and evaluated whether referee decisions were correct, contentious or incorrect.

Physiological measurement during fitness tests and matches

Heart Rate and Blood Lactate concentration:

Heart rate (HR) was measured and recorded continuously throughout the two fitness tests (FIFA Fitness tests and Yo-Yo IET-2) using a short range radio telemetry chest strap and wrist watch receiver (POLAR, S5800, Kempele, Finland) with data captured at 5 seconds intervals. The HR monitor was attached to the referees 30 min before warming up and removed 10 min post-tests. During matches, HR was also measured and recorded continuously using the same methods: the device was fitted to the referees 45 minutes before the kick-off and removed 10 minutes post-match with data captured at 5 s intervals. At the end of the matches, data were stored in the watch and then downloaded on a computer using the Polar precision 3.0 software (Polar, Kempele, Finland).

For Fitness tests, blood samples were taken for blood lactate concentration analysis at rest and within 1 min of completing the Endurance (1000 m) test (FIFA Fitness Test) or the Yo-Yo IET-2. Blood samples were analysed immediately to determine blood lactate concentration using a portable electroenzymatic device (Lactate Pro Portable Lactate Analyser, Japan). During actual matches, blood samples were collected from finger-pricks for the determination of lactate concentration at 3 times: rest (pre-match), and within 2 min of the end of the first half (half-time) and the second half (post-match). Blood samples were analysed immediately to determine blood lactate concentration using the same portable electroenzymatic device used for the fitness tests. Clinical waste was then disposed of at the nearby University of Sulaimani (Appendix 2) via commercial clinical waste disposal operators.

Session Rating of Perceived Exertion (RPE)

Session RPE has been used as an effective tool for physical activity load in team sports for athletes (players and officials) (Weston *et al.* 2010; Impellizzeri *et al.* 2004; Foster 1998). Therefore, each referee was asked to express the session RPE (relating to the half just completed) 10 min after the 1st half and 10 min post-match by using the scale of Borg's CR10-scale modified by (Foster *et al.* 2001) (see Figure 4.1).

Subjects were required to review the RPE Scale (Foster et al. 2001) and select a number that corresponds to how hard they perceived themselves to have worked overall for the exercise bout or session just completed. Verbal and written instructions stated that participants "*must give one single rating to reflect the whole session, overall. This feeling should reflect how heavy and strenuous the exercise felt to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any other factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion as overall*". Further explanations also detailed that "*the scale ranges from 0 to 10 (Figure 4.1), where 0 means no exertion – "Rest" and 10 means maximal exertion, "Maximal". Choose the number from below that best describes your* session or exercise *bout. You will see that from the rating of "Hard" (5) up to "Maximal" (10) there are some numbers without corresponding descriptions. This is to provide you with a range you may rate yourself in between "Hard" up to "Maximal". Try to determine your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to others and you will rate by asking yourself*"

Rating	**Descriptor**
0	**Rest**
1	**Very, Very Easy**
2	**Easy**
3	**Moderate**
4	**Somewhat Hard**
5	**Hard**
6	*****
7	**Very Hard**
8	*****
9	*****
10	**Maximal**

Figure 4.1: Foster *et al.* (2001) RPE Chart

Fitness Tests

FIFA fitness tests (pre-June 2016 battery):

FIFA recommended a fitness test for Futsal referees to all member associations in the world. The pre-2016 FIFA test contained a 1000 m run ("Endurance" test), a 40 m ("Sprint" test) and 80 m "Agility" test (FIFA 2010), in the following sequence:

1. 1000 m Endurance test, within 4 min
2. Break for 15 min
3. 40 m Sprint test, within 10 seconds (Figure 4.2)
4. Break for 5 min
5. 80 m Agility test, within 20.5 seconds (Figure 4.3)
6. Break for 5 min
7. 40 m Sprint test, within 10 seconds
8. Break for 5 min
9. 80 m Agility test, within 20.5 seconds (FIFA 2010)

For the endurance test referees must cover 1000 m in 4 min; for the sprint test (40 m), they should cover 40 m sprint in less than 10 seconds; and for agility test they must cover the 80 m course in less than 20.5 seconds. The sprint and agility tests were repeated twice at the same test day (FIFA 2010).

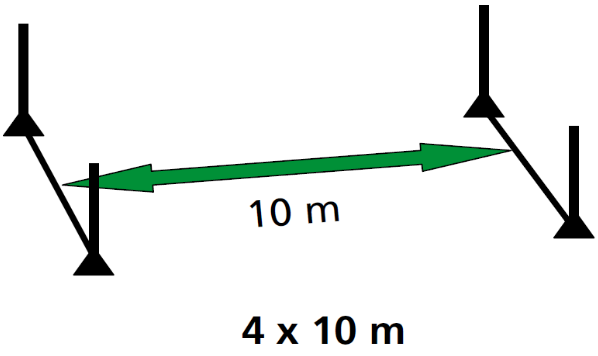


Figure 4.2, speed test (FIFA 2010)

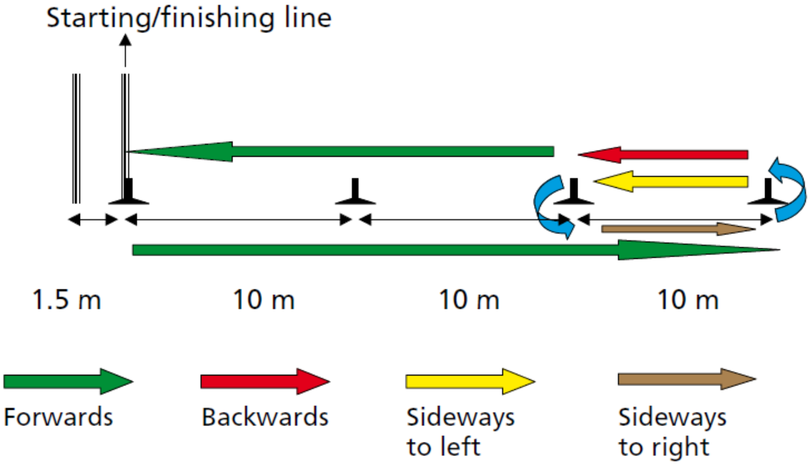


Figure 4.3, agility test (FIFA 2010)

Yo-Yo Intermittent Endurance Test Level 2 (Yo-Yo IET-2):

This test requires intermittent exercise consisting of repeated 20 m shuttle runs (Bradley et al., 2011) and it was performed indoors (on a Futsal pitch). After each 40 m (2 × 20 m runs) participants have a 5 s rest of jogging around a marker placed 2.5 m behind the starting/finishing line. The pace of each shuttle is dictated by an audible tone played through a loud speaker. The speed is increased regularly until the participant is unable to continue with the required pace (Figure 4.4).

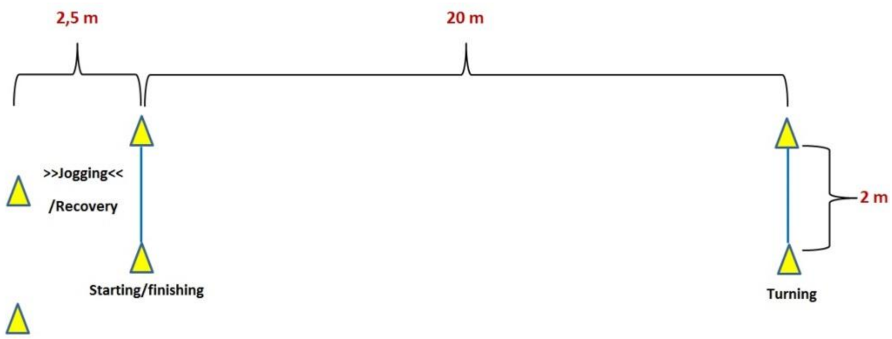


Figure 4.4: Yo-Yo IET-2

Statistical Analysis

Statistical analyses were carried out using SPSS (23 Amonk, NY: IBM Corp). Data are presented as means ± standard deviation (SD) and significance was accepted when $p < 0.05$. For comparison between the first and second halves for each activity (distance, duration and activity frequency) and also for comparison between match-time and clock time, values were compared using paired samples t-tests (and decision-making performance [missed fouls] between 1st and 2nd halves) (or Repeated Measures ANOVA for blood lactate due to 3 repeated time points) when parametric assumptions were met.

If data were not normally distributed they were first normalised with log transformation using the natural log (comparisons for the total activity frequency between match-time and clock time among activities and also comparisons between the FIFA endurance test and the Yo-Yo IET-2 with all activities at clock time) or square root transformation (distance from incident).

If data could not be normalised then non-parametric tests were used: Wilcoxon matched pairs test (1st vs 2nd half activity profile results for walking, jogging, LIR, MIR, HIR, sprint, BW and SW; HR and RPE, and decision-making [correct, contentious, incorrect decisions]).

Pearson correlation was used to compare FIFA endurance test and the Yo-Yo IET-2 performance with total distance at match-time and clock time, and also compare fitness tests with total distance of all activities (walking, jogging, LIR, MIR, HIR, sprint, SW and BW) at match-time (FIFA endurance test and the Yo-Yo IET-2 were compared with all activities at clock time after log transformation of the variables to normalise data distribution). Pearson correlation was also used to compare the FIFA endurance test and the Yo-Yo IET-2 performance with decision-making performance.

IV. Results

Motion analysis

Motion Analysis Distances:

The total distance covered in match time was significantly higher than clock time (5943.6 ± 414.7 vs. 3374.0 ± 215.3 m, $t = 33.59$, $p < 0.001$) (Table 4.1), and also the TD covered at the first half in match time was significantly higher ($p < 0.05$) than second half (3093.5 ± 271.3 m vs. 2850.1 ± 219.1 m, $t = 3.87$, $p = 0.001$) (Table 4.2), thus the total distance covered over the period of an entire match (79.58 ± 6.34 min) was 5943.6 ± 414.7 m. There were significant differences between match time and clock time for all activities $p < 0.001$ (Table 4.1). Distance covered for LIR, MIR, HIR and SW were significantly higher ($p < 0.05$) in the first half compared to the second half, but walking distance was significantly lower ($p < 0.05$) in the first half compared to the second 812.4 ± 161.2 m vs. 929.0 ± 117.1 m ($t = -2.91$, $p = 0.010$) (Table 4.2).

For 1st and 2nd halves comparison at clock time, TD in the 1st half was significantly higher ($p < 0.05$) compared to the second half for LIR, MIR, SW & total distance. There was a trend ($p = 0.059$) for TD of SPR to be higher in the first vs second half (54.6 ± 27.5 vs 43.0 ± 36.2). However, there were no significant ($p > 0.05$) differences at walking, jogging, HIR and BW (Table 4.3).

Table 4.1: Overall Motion Analysis Distances results for clock-time and match time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Distance (m) as Sum	Clock-time (Ball in play)	0 ± 0	901.0 ± 157.0	392.4 ± 103.1	443.5 ± 65.4	403.6 ± 88.5	170.6 ± 88.9	97.6 ± 45.2	372.4 ± 74.4	593.0 ± 111.0	3374.0 ± 215.3
	Match-time	0 ± 0	1741.4 ± 225.1	754.9 ± 162.5	774.0 ± 100.9	635.9 ± 103.1	275.5 ± 91.5	149.0 ± 59.2	654.7 ± 149.3	958.1 ± 230.9	5943.6 ± 414.7
	Statistical analysis values (t/z,p)	0	t = 17.59, p < 0.001	t = 15.59, p < 0.001	t = 19.59, p < 0.001	z = -3.72, p < 0.001	z = -3.72, p < 0.001	t = 8.45, p < 0.001	t = 11.21, p < 0.001	t = 10.09, p < 0.001	t = 33.59, p < 0.001
% of total distance when the unit is Sum	Clock-time (Ball in play)	0 ± 0	26.8 ± 5.0	11.5 ± 2.7	13.1 ± 1.8	11.9 ± 2.1	5.1 ± 2.7	2.9 ± 1.3	11.0 ± 1.9	17.6 ± 3.3	100.0 ± 0.0
	Match-time	0 ± 0	29.4 ± 4.3	12.7 ± 2.3	13.1 ± 1.9	10.7 ± 1.2	4.6 ± 1.4	2.5 ± 0.9	11.0 ± 2.3	16.1 ± 3.5	100.0 ± 0.0

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Table 4.2: Motion Analysis Distances results (1st & 2nd halves) during match time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Distance (m) as Sum	First Half	0 ± 0	812.4 ± 161.2	384.6 ± 118.7	425.9 ± 73.7	360.3 ± 63.8	161.1 ± 83.0	81.7 ± 30.7	327.2 ± 87.6	540.3 ± 152.0	3093.5 ± 271.3
	Second Half	0 ± 0	929.0 ± 117.1	370.3 ± 120.6	348.1 ± 78.3	275.6 ± 65.1	114.4 ± 33.2	67.4 ± 57.6	327.5 ± 93.6	417.8 ± 103.7	2850.1 ± 219.1
	Statistical analysis values (t/z,p)	0, 0	t = -2.91, p = 0.010	t = 0.34, p = 0.733	t = 3.16, p = 0.006	z = -3.20, p = 0.001	t = 2.52, p = 0.022	t = 1.94, p = 0.068	t = -0.012, p = 0.991	t = 4.58, p < 0.001	t = 3.87, p = 0.001

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Table 4.3: Motion Analysis Distances results (1st & 2nd halves) during clock time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Distance (m) as Sum	First Half	0 ± 0	428.4 ± 120.0	198.1 ± 68.7	252.6 ± 50.4	224.0 ± 59.6	102.6 ± 86.3	54.6 ± 27.5	186.3 ± 47.1	336.7 ± 87.1	1783.4 ± 164.0
	Second Half	0 ± 0	472.6 ± 70.1	194.2 ± 66.8	190.9 ± 51.2	179.6 ± 58.8	68.0 ± 22.8	43.0 ± 36.2	186.0 ± 61.6	256.3 ± 57.5	1590.6 ± 154.8
	Statistical analysis values (t/z,p)	0, 0	t = -1.58, p = 0.131	t = 0.18, p = 0.853	t = 3.45, p = 0.003	t = 2.69, p = 0.016	t = 1.43, p = 0.169	t = 2.02, p = 0.059	t = 0.01, p = 0.988	t = 3.50, p = 0.003	t = 3.47, p = 0.003

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Motion Analysis Durations

For all activities (standing, walking, jogging, LIR, MIR, HIR, PSR, BW and SW) the duration at match-time was significantly ($p < 0.001$) higher than clock time (Table 4.4). In regards to the first and second halves at match time, the total duration was significantly ($p < 0.05$) different, respectively 2335.2 ± 219.4 s vs 2439.7 ± 185.4 s ($t = 3.09$, $p = 0.007$) (Table 4.5). Moreover, total duration at match time for standing and walking at the first half was significantly ($p < 0.05$) lower than the second half, respectively 555.4 ± 130.0 s vs 669.9 ± 125.2 ($t = - 3.80$, $p = 0.001$) and 744.9 ± 155.8 vs 881.2 ± 141.5 s ($t = -3.78$, $p = 0.001$), and also total duration for LIR, MIR, HIR and SW was significantly ($p < 0.05$) higher than the second half, respectively 153.9 ± 29.6 vs 125.2 ± 28.1 s ($t = 3.11$, $p = 0.006$), 97.8 ± 17.3 vs 74.0 ± 17.4 s ($t = 4.88$, $p < 0.001$), 36.1 ± 18.3 vs 25.6 ± 7.9 s ($t = 2.53$, $p = 0.021$) and 315.1 ± 103.4 vs 253.1 ± 81.7 s ($t = 3.62$, $p = 0.002$), however there was no significant differences ($p > 0.05$) for jogging, SPR and BW (Table 4.5).

For 1^{st} and 2^{nd} halves comparison at clock time for activity durations the 1^{st} half was significantly higher ($p < 0.05$) compared to the second half for LIR, MIR, SPR and SW, but referees spent more time standing in the second half compared to the first half 216.1 ± 55.2 vs 277.7 ± 64.4 s ($t = -3.58$, $p = 0.002$) (Table 4.6). However, there were no significant ($p > 0.05$) differences for jogging, HIR, BW and walking during clock-time (Table 4.6).

Table 4.4: Overall Motion Analysis Duration results for clock-time and match time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Duration (s)	Clock-time (Ball in play)	493.8 ± 95.3	805.3 ± 128.7	210.5 ± 60.9	160.0 ± 25.7	108.4 ± 23.3	38.1 ± 19.8	17.1 ± 7.5	234.5 ± 39.2	332.4 ± 65.0	2400.0 ± 0.0
	Match-time	1225.3 ± 221.1	1626.2 ± 255.5	402.9 ± 89.9	279.1 ± 39.0	171.8 ± 28.0	61.7 ± 20.3	26.8 ± 10.8	413.0 ± 96.4	568.1 ± 167.9	4774.8 ± 380.1
	Statistical analysis values (t/z,p)	t = 15.79, p < 0.001	t = 15.07, p < 0.001	t = 15.67, p < 0.001	t = 18.38, p < 0.001	z = -3.72, p < 0.001	z = -3.72, p < 0.001	t = 8.97, p < 0.001	t = 11.67, p < 0.001	t = 7.76, p < 0.001	t= 26.50, p < 0.001
% of total time (s)	Clock-time (Ball in play)	20.6 ± 4.0	33.6 ± 5.4	8.8 ± 2.5	6.7 ± 1.1	4.5 ± 1.0	1.6 ± 0.8	0.7 ± 0.3	9.8 ± 1.6	13.9 ± 2.7	100.0 ± 0.0
	Match-time	25.5 ± 3.2	34.0 ± 3.9	8.5 ± 2.0	5.9 ± 0.8	3.6 ± 0.5	1.3 ± 0.4	0.6 ± 0.2	8.7 ± 2.0	12.0 ± 3.5	100.0 ± 0.0

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Table 4.5: Motion Analysis Duration results (1st & 2nd halves) during match time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Duration (s)	First Half	555.4 ± 130.0	744.9 ± 155.8	206.6 ± 66.9	153.9 ± 29.6	97.8 ± 17.3	36.1 ± 18.3	15.3 ± 5.6	210.1 ± 64.6	315.1 ± 103.4	2335.2 ± 219.4
	Second Half	669.9 ± 125.2	881.2 ± 141.5	196.3 ± 62.3	125.2 ± 28.1	74.0 ± 17.4	25.6 ± 7.9	11.5 ± 10.3	202.9 ± 65.5	253.1 ± 81.7	2439.7 ± 185.4
	Statistical analysis values (t/z,p)	t = - 3.80, p = 0.001	t = -3.78, p = 0.001	t = 0.47, p = 0.643	t = 3.11, p = 0.006	t = 4.88, p < 0.001	t = 2.53, p = 0.021	z = -1.63, p = 0.102	t = 0.34, p = 0.732	t = 3.62, p = 0.002	t = - 3.09, p = 0.007

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Table 4.6: Motion Analysis Duration results (1st & 2nd halves) during clock time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Duration (s) as Sum	First Half	216.1 ± 55.2	378.9 ± 101.7	108.3 ± 40.3	91.5 ± 19.2	60.5 ± 15.7	22.8 ± 19.1	10.2 ± 5.1	122.1 ± 37.5	189.5 ± 55.6	1200.0 ± 0.0
	Second Half	277.7 ± 64.4	426.4 ± 63.8	102.1 ± 34.4	68.5 ± 18.4	47.9 ± 15.3	15.2 ± 5.3	6.9 ± 5.9	112.4 ± 38.0	142.9± 30.9	1200.0 ± 0.0
	Statistical analysis values (t/z,p)	t = -3.58, p = 0.002	t = -1.81, p = 0.087	t = 0.60, p = 0.552	t = 3.59, p = 0.002	t = 2.89, p = 0.010	t = 1.43, p = 0.170	t = 2.59, p = 0.019	t = 0.63, p = 0.532	t = 3.50, p = 0.006	0, 0

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Motion Analysis Frequency:

Significantly more ($t = 31.63$, $p < 0.001$) activities were recorded during match time (1539.2 ± 129.9) compared to clock time (853.4 ± 76.4) (Table 4.7). The total frequency for all activities at the first half in match time was significantly higher ($p < 0.001$) than second half (Table 4.8). There was no significant difference between the 1st and 2nd halves ($p > 0.05$) for match time activities (774.6 ± 78.6 and 764.6 ± 63.6, respectively) (Table 4.8) but there was significant ($p < 0.05$) differences in the first half compared to the second half for standing, walking, LIR, MIR, HIR, SPR and SW (Table 4.8), however there was no significant difference ($p > 0.05$) for jogging and BW (Table 4.8).

There was no significant difference ($t = 0.70$, $p = 0.945$) between the first and second halves for number of activities recorded at clock time (426.9 ± 38.2 and 426.5 ± 41.6, respectively) (Table 4.9). Significantly more activities were recorded in the first compared to the second half for LIR, MIR, SPR and SW, respectively 25.8 ± 6.2 vs 18.5 ± 3.9 ($t = 4.09$, $p = 0.001$), 18.5 ± 5.0 vs 13.8 ± 5.1 ($z = -2.96$, $p = 0.003$), 3.8 ± 1.0 vs 2.6 ± 1.8 ($z = - 2.38$, $p = 0.017$) and 71.1 ± 16.6 vs 57.1 ± 11.7 ($t = 3.54$, $p = 0.002$) (Table 4.9).

The frequency of standing was significantly lower ($P<0.05$) in the first half compared to the second half 128.2 ± 14.7 vs 147.1 ± 18.4 ($t = -4.88$, $p < 0.001$) during clock-time (Table 4.9). However, there were no significant differences ($p > 0.05$) between the first and second halves for walking, jogging, HIR and BW (Table 4.9).

Table 4.7: Overall Motion Analysis Frequency results for clock-time and match time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Frequency (n)	Clock-time (Ball in play)	275.3 ± 29.0	230.3 ± 48.4	51.2 ± 14.4	44.3 ± 7.1	32.3 ± 8.8	11.2 ± 3.9	6.4 ± 2.2	74.2 ± 16.2	128.2 ± 23.4	853.4 ± 76.4
	Match-time	505.1 ± 37.6	438.7 ± 77.0	99.4 ± 26.7	76.0 ± 9.0	51.5 ± 11.0	18.4 ± 5.0	9.9 ± 3.4	127.1 ± 26.4	213.2 ± 47.1	1539.2 ± 129.9
	Statistical analysis values (t/z,p)	t = 31.20, p < 0.001	t = 18.06, p < 0.001	t = 13.35, p < 0.001	t = 29.42, p < 0.001	t = 17.10, p < 0.001	t = 14.54, p = 0.001	t = 10.64, p < 0.001	t = 12.17, p < 0.001	t = 11.19, p < 0.001	t = 31.63, p < 0.001
% of total Frequency (n)	Clock-time (Ball in play)	32.4 ± 3.9	26.9 ± 4.4	6.0 ± 1.6	5.2 ± 0.8	3.8 ± 1.0	1.3 ± 0.5	0.8 ± 0.2	8.7 ± 1.5	15.0 ± 2.1	100.0 ± 0.0
	Match-time	33.0 ± 3.3	28.4 ± 3.8	6.4 ± 1.6	5.0 ± 0.6	3.3 ± 0.6	1.2 ± 0.3	0.6 ± 0.2	8.2 ± 1.4	13.8 ± 2.5	100.0 ± 0.0

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Table 4.8: Motion Analysis Frequency results (1st & 2nd halves) during match time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Frequency (n)	First Half	242.1 ± 19.6	207.7 ± 50.1	52.8 ± 18.9	43.2 ± 8.3	29.5 ± 5.8	10.5 ± 3.9	5.6 ± 1.4	64.4 ± 13.4	118.9 ± 30.8	774.6 ± 78.6
	Second Half	262.9 ± 29.1	231.0 ± 33.3	46.7 ± 17.2	32.8 ± 4.8	22.0 ± 6.4	7.9 ± 2.1	4.3 ± 3.0	62.7 ± 21.4	94.3 ± 20.9	764.6 ± 63.6
	Statistical analysis values (t/z,p)	t = -2.73, p = 0.014	t = -2.73, p = 0.014	t = 1.06, p = 0.303	z = -3.02, p = 0.002	z = -3.41, p = 0.001	t = 2.79, p = 0.013	t = 2.81, p = 0.012	t = 0.30, p = 0.764	t = 4.44, p < 0.001	t = 0.70, p = 0.488

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Table 4.9: Motion Analysis Frequency results (1^{st} &# 2^{nd} halves) during clock time

		Standing	Walking	Jogging	LIR	MIR	HIR	SPR	BW	SW	Total
Frequency (n) as Sum	First Half	128.2 ± 14.7	107.9 ± 33.3	27.6 ± 10.5	25.8 ± 6.2	18.5 ± 5.0	6.6 ± 4.0	3.8 ± 1.0	37.5 ± 10.8	71.1 ± 16.6	426.9 ± 38.2
	Second Half	147.1 ± 18.4	122.4 ± 23.4	23.7 ± 7.6	18.5 ± 3.9	13.8 ± 5.1	4.6 ± 1.4	2.6 ± 1.8	36.7 ± 14.4	57.1 ± 11.7	426.5 ± 41.6
	Statistical analysis values (t/z,p)	t = -4.88, p < 0.001	t = -1.98, p = 0.064	z = -1.32, p = 0.187	t = 4.09, p = 0.001	z = -2.96, p = 0.003	t = 1.62, p = 0.122	z = - 2.38, p = 0.017	t = 0.18, p = 0.859	t = 3.54, p = 0.002	t = 0.70, p = 0.945

Values are mean ± SD (n=18). BW = backwards; SPR = sprint; SW = sideways.

Statistical analysis values (t/z, p) show comparisons between First Half and Second Half (t when parametric, z when non-parametric tests used).

Physiological and perceptual characteristics during the match:

Mean heart rate for the whole match was 147.7 ± 1.3 bpm (peak 188.0 bpm ± 10.2). The heart rate average was significantly higher ($p < 0.001$) ($z = -3.50$, $p < 0.001$) in the first half compared to the second half (Table 4.10).

Blood lactate concentration changed significantly across times ($F = 22.86$, $p < 0.001$) with post hoc analysis revealing significant elevations above pre-match at half time (1.98 ± 0.53, $p < 0.001$) and post-match (2.12 ± 0.41 mmol/L, $p < 0.001$ with no difference between the half-time and post-match values ($p = 1.000$) (Table 4.10). ($p > 0.05$). For session RPE, there was no difference at half time compared to post-match (6.8 vs 7.1, $p > 0.05$) ($z = -0.90$, $p > 0.05$) (Table 4.10).

Table 4.10: Physiological and perceptual measures

	Pre match	**Half-time / First half**	**Post-match / Second half**	Statistical analysis values (F/z, p)
Blood lactate (mM)				
	1.27 ± 0.32	1.98 ± 0.53	2.12 ± 0.41	F = 22.86, p < 0.001 ** for post hoc details see legend
Heart rate (BPM)				
	-	150.9 ± 1.9	144.5 ± 2.6	z = - 3.50, p < 0.001
Session RPE				
	-	6.8 ± 1.3	7.1 ± 0.7	z = - 0.90, p = 0.365

Values are mean ± SD (n=18).

Statistical analysis values (F/z,p) show comparisons between Half-time/First Half and Post-match/Second Half (and pre-match for lactate), (F when parametric, z when non-parametric tests used).

**Blood lactate post hoc: pre-match vs half time ($p < 0.001$); pre-match vs post-match ($p < 0.001$); half-time vs post-match ($p = 0.42$).

Assessment of referee decision making performance:

There were 178 situations in total across all 9 matches. This included 151 referee decisions and 27 missed fouls with an average of 17 (range 10 to 21) decisions made per match. The proportion of correct, incorrect and contentious decision are shown in Table 4.11. On average, referees were further away from the incident for incorrect (13.3 ± 5.4 m) compared to correct decisions (9.2 ± 4.6 m, t = -3.36, p = 0.001).

Table 4.11: Assessment of referee decision-making performance.

Decisions made	**1st half**	**2nd half**	**Whole match**	Statistical analysis values (t/z, p)
Correct	91.1 ± 14.9%	73.3 ± 17.4%	81.3 ± 11.8% (123/151 decisions)	z = -2.71, p = 0.007
Contentious	1.7 ± 5.3%	8.8 ± 14.8%	6.5 ± 9.3% (9/151 decisions)	z = -1.82, p = 0.068
Incorrect	7.2 ± 14.4%	17.9 ± 17.1%	12.2 ± 11.3% (19/151 decisions)	z = -2.04, p = 0.041
Total decisions (151)	46% (69)	54% (82)	100%	
Missed fouls	24.8 ± 18.4%	75.2 ± 18.4%	100% (27 incidents)	t = -4.56, p = 0.002

Values are mean ± SD (n=18). Statistical analysis values show comparisons between 1st half and 2nd half.

FIFA Fitness Tests and Yo-Yo IET-2:

Mean performance in the endurance test was 3.51 ± 0.04 min (Table 4.12) and Yo-Yo IET-2 distance was 1160.0 ± 147.3 m (Table 4.13) (Figure 4.6). There was a significant correlation between the Yo-Yo IET-2 performance and total match distance covered at clock time ($r = 0.720$, $p = 0.019$) but not match time ($r = 0.076$; $p = 0.834$). There was a significant correlation between the Yo-Yo IET-2 performance and clock time jogging distance ($r = 0.658$, $p = 0.038$) and match time jogging distance ($r = 0.827$; $p = 0.003$). There was no correlation between the endurance test (1000 m) and total distance covered at match time ($r = -0.54$, $p = 0.883$) or at clock time ($r = -0.295$, $p = 0.409$). There was no correlation between the endurance or the Yo-Yo IET-2 and the HIR during match time ($r = -0.174$, $p = 0.630$) or clock time ($r = -0.110$, $p = 0.762$), respectively ($n = 10$). There was no correlation between the endurance or the Yo-Yo IET-2 and any other activity profile measures (all $p > 0.05$). There were no correlations between the endurance test ($r = -0.16$, $p = 0.650$) or the Yo-Yo IET-2 ($r = 0.09$, $p = 0.795$) and proportion of correct decisions. There was also no correlation between the endurance test ($r = 0.32$, $p = 0.35$) or the Yo-Yo IET-2 ($r = -0.009$, $p = 0.980$) and the change incorrect decisions percentage from the 1st to 2nd half.

Table 4.12: FIFA fitness test results (timing of reference and blood lactate)

FIFA fitness test; Pass (FIFA reference time) 1000 m: 4 min Sprint: 10 s Agility: 20.5 s	Endurance test (1000 m)	First Sprint test (40 m)	First Agility test (80 m)	Second Sprint test (40 m)	Second Agility test (80 m)
Time (min, s)	3.51 ± 0.04 m	9.67 ± 0.2 s	18.33 ± 0.7 s	9.73 ± 0.1 s	19.07 ± 0.6 s
HR	169.0 ± 3.7	151.8 ± 5.2	169.1 ± 5.0	155.5 ± 6.9	162.8 ± 9.1
BL	Pre-endurance test		Post- endurance test		
	0.9 ± 0.2		6.9 ± 1.0		

(Mean ± SD (n=10))

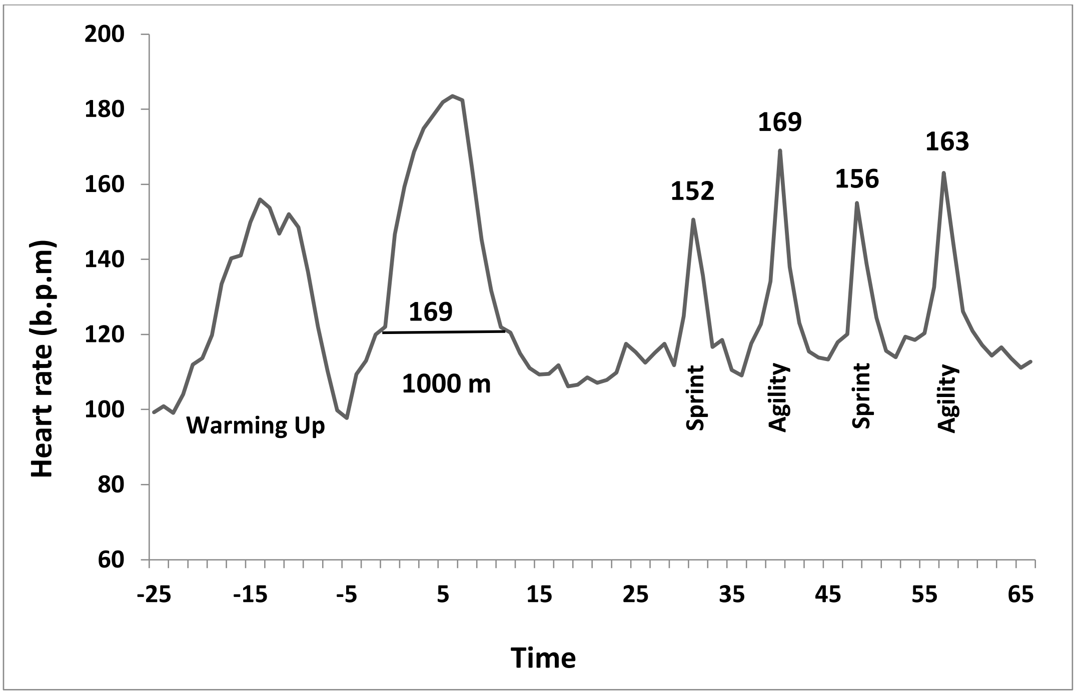


Figure 4.5: Representative FIFA fitness tests (n=10). Time axis is not to scale

Table 4.13: Yo-Yo IET-2 test results

Yo-Yo IET-2 results	Minimum level	Maximum level	Total distance, HR average
Time (min, s)	14.2	15.1	1160.0 ± 147.3 m
HR	125	202	170.4 ± 3.9
BL	Pre-test		Post-test
	1.0 ± 0.2		8.4 ± 1.7

(Mean ± SD (n=10))

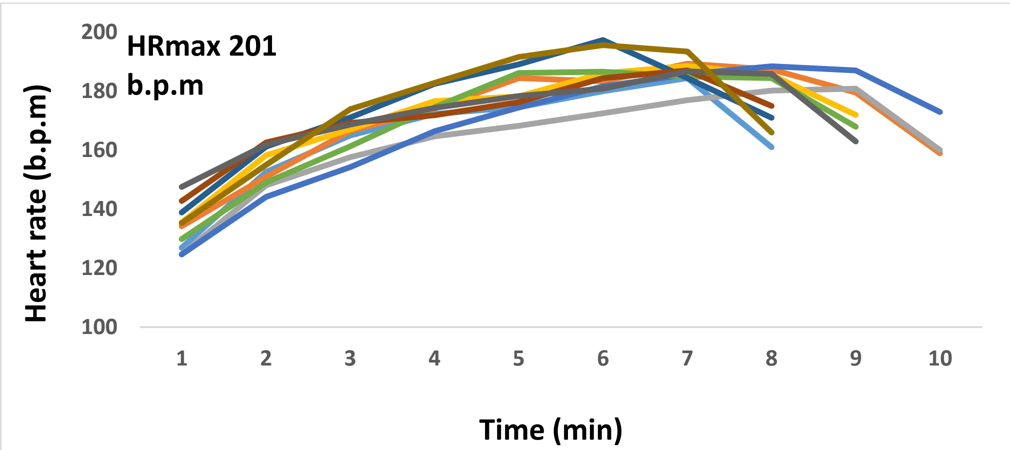


Figure 4.6: Representative the Yo-Yo - IET-2 (n=10).

V. Discussion

The main findings of the present study were Futsal referees' motion analysis parameters decreased in the second half and this may be related to fatigue (physical and mental) in the latter stages of the match. Also, activity pattern differences compared to previous research could reflect the FIFA rule change (2010). These results suggest that referees suffer fatigue in the second half, which differs from what has been observed in previous studies on players, in which players have been seen to cover similar distances in each half (Dogramaci, Watsford and Murphu 2011; Castagna *et al.* 2009) although high intensity running was reduced in the second half (Castagna *et al.* 2009). This can be explained by the fact that unlimited rolling substitutions are allowed in Futsal with players typically covering 3-5 km per match (Makaje *et al.* 2012; Dogramaci, Watsford and Murphu 2011; Castagna *et al.* 2009; Doğramacı and Watsford 2006) whereas Futsal referees must officiate the whole match continually (and may cover double this distance). However, it must be acknowledged that the present study did not analyse the players. Since the activity of referees is dictated by the activity of the game, and previous research on Futsal players has shown that greater distance covered is observed in higher level (i.e. elite vs amateur) players (Makaje *et al.* 2012; Dogramaci, Watsford and Murphu 2011) along with the fact that players seem to cover less distance and also show less evidence of decreasing towards the end of matches shows the importance of conducting analysis on referees rather than making assumptions based on analyses of players. The physiological and perceptual measures in the present study lend some support to this and the referees' motion analysis data (suggesting referee fatigue).

The findings of the present study showed that total distance was similar (2013/14 season, after the FIFA rule change) to the previous study (2005/6 season, before the FIFA rule change, Rebelo et al., 2011) but distribution of activity types/activity profile differed. The total number of activities performed in the present study (1539 ± 130) is slightly higher than the previous study and total match duration is similar to previous Futsal studies (Dixon 2014a; Rebelo *et al.* 2011; Doğramacı and Watsford 2006). There was a higher amount of jogging, sprinting and backwards running, and less walking in the present study (compared to Rebelo *et al.*, 2011) whereas the amount of LIR, MIR, HIR and sideways running were similar. This could be a result of changes to the match activity profile that have occurred since the FIFA rule change as referees' activity is directly influenced by match play.

Rebelo *et al.* (2011) observed that the mean HR for Futsal referees was lower in the second (143 bpm) compared to first half (149 bpm). For football many report that performance intensity and tempo of play is reduced in the second half (Krustrup *et al.* 2009; Da Silva, Fernandes and Fernandez 2008; Mallo *et al.* 2008; Weston, Drust and Gregson 2011; Krustrup and Bangsbo 2001; Catterall *et al.* 1993) and it is possible that similar patterns occur in Futsal. However, in football this can be attributed to increased fatigue of players and changes in the velocity of the game (Barbero-Alvarez *et al.* 2012) but Krustrup *et al.* (2009) report it could be influenced by the referee's fitness (e.g. they become less able to "keep up" with play). For Futsal, given the smaller decrements reported in players' activity, and unlimited rolling substitutions, player fatigue may be less of a factor and the results observed here may be more related to referees' fitness. This information may aid fitness coaches to optimise training and, perhaps most importantly, for associations to determine the best methods and tests to assess referees' fitness. However, it will be valuable for future research to collect data from referees and players during the same matches to further advance understanding of the relationship between match profile and physical performance of referees.

The decrease in decision-making performance and increase in missed fouls in the 2^{nd} half are in line with research on football referees and assistant referees, whereby the likelihood of incorrect decisions was increased towards the end of a match (Krustrup and Bangsbo, 2001 and Mallo et al., 2012). This may be related to fatigue (physical and mental) in the latter stages of the match. However, this was not confirmed by a correlation between fitness measures and 1^{st}-to-2^{nd} half changes in decision-making, but the relationship between fitness and decreases in measures of performance (that are likely influenced by both mental and physical fatigue in synergy) are likely to be more complex and will require further research, which is beyond the scope of the present study.

In the present study the results for referee position showed that referees were on average ~4 m further away from the infringement for incorrect compared to correct decisions. This may be a result of referees failing to be in the optimal position (i.e. keeping up with play) due to fatigue (physical and/or mental). In the study of Mallo et al. (2012) less incorrect decisions were made when referees were between 11 to 15 m from the incident compared to being further away and similar findings have been reported in other football research (Krustrup and Bangsbo 2001). Although those findings were in football and not Futsal it demonstrates the importance of positioning (or keeping up with play) and supports the findings of the present study. It must also be noted that this relationship was not evident in football assistant referees (Gilis et al. 2008).

Relationships between fitness tests performance and match activity profile

FIFA recently changed the fitness testing battery for Futsal referees and have replaced the old test (which included a 1000 m "endurance" run, 40 m sprint and 80 m agility run) with a new test battery that includes a modified version of the Yo-Yo (ARIET). Dixon (2014b) and Rebelo *et al.* (2011) pointed out that the 1000 m test does not seem an appropriate reflection of the referee's ability and lacks external validity or sports-specificity for Futsal refereeing. Both authors have suggested the Yo-Yo IET-2 is more appropriate. Our findings support the notion that this new testing battery is better suited to determine referees' suitability (in terms of fitness). It was observed a significant positive correlation between Yo-Yo test performance and jogging distances (clock time and match time) and between Yo-Yo test performance and total clock time distance, which is in agreement with the findings of Rebelo *et al.* (2011). There was no correlation, however, between Yo-Yo test performance and total match time distance and observed significant differences between match time and clock time motion analysis results. This could be explained by the fact that match time includes many periods of rest and non-active periods (including stoppages in play) so a greater proportion of match time is spent in activities that are less physically demanding and/or related to fitness. This observation highlights the importance of studying clock time and our data provide preliminary evidence that clock-time statistics may be more important (i.e. this contains the periods when referees are exposed to most physiological demands, and must keep up with play, view and make decisions on incidents). There was also no correlation between the 1000 m run performance and match activity, further supporting the suggestion that this test lacks relevance and sport-specificity but the lack of correlation between the Yo-Yo test and many other parameters of the motion analysis may suggest that although this test is better it is still not ideal in this context. Further studies directly examining the relationships between performance on this new testing battery and match activity and/or performance of referees are still needed. It is also worthy of note that Futsal referees ran backwards 654.7 ± 149.3 m in the present study and the latest FIFA fitness tests for Futsal referees does not include backwards running, highlighting the scope for further development and improvement (sport-specificity) of the testing battery. It is also important to note that a referee's activity profile may be influenced not only by their fitness but also by their experience, skill, game awareness and effective positioning.

These factors may influence the nature of any relationships between activity profile and fitness levels, which is a limitation when using simple correlations between such measurements.

Practical Applications

- Futsal referees suffer fatigue in the second half, which may have practical implications for their ability to perform optimally (e.g. keep up with play in order to make decisions).
- Futsal referees made a greater proportion of incorrect decisions in the second half.
- The 2^{nd} half decrements of total distance may be related to sports-specific fitness levels (and although this did not correlate with fitness test performance, sport-specific fitness for referees may also include resistance to physical and mental fatigue combined).
- Fitness coaches can use the above information to optimise training with the aim of improving sports-specific fitness in referees.
- The new FIFA testing battery for Futsal referees seems better suited to determine sport-specific fitness due to better relationships with match activity profile. However, this battery still lacks any assessment of backwards movements, which could be incorporated in the future to increase specificity further.

Limitations

Only referees were assessed in the present study and not players. However, the activity of referees is dictated by the activity of the game, and hence the players. To better understand and explore such relationships it will be valuable for future research to collect data from referees and players during the same matches. It is also important to note that a referee's activity profile may be influenced by factors other than fitness, such as experience, skill, game awareness and effective positioning. These factors may influence the nature of any relationships between activity profile and fitness levels. Future research may benefit from incorporating this into the analysis and interpretation of results, although this is not an easy task (i.e. it will require an accurate and valid 'measure' of these parameters [e.g. experience, skill, game awareness] but these may be difficult to quantify). Such studies may also require relatively large samples sizes in order to ensure sufficient numbers in each category.

Conclusion

In conclusion, the present findings show that the referees covered a similar total distance to that previously reported (pre 2010 rule change). However, there appears to be some differences in activity types/patterns, which could be a result of the rule change and/or could reflect the different study populations (i.e. Portuguese vs Iraqi). There were reductions in second half parameters (total distance and heart rate) and an increase in the percentage of incorrect decisions and missed fouls, which could be due to changes in the tempo/intensity of the game (i.e. player fatigue), referee fatigue (combined mental and physical), or a combination of all factors. Further motion analysis studies are needed to collect data for referees and players during the same matches. The present study also suggests that the traditional FIFA fitness test (and 1000 m run) were poor for assessing Futsal referee-specific fitness, and tests that involve intermittent and/or direction changes, such as the Yo-Yo test or ARIET, may be more appropriate, although further research is needed on the ARIET in this context.

Chapter 5

Does the Psychomotor Vigilance test (PVT) influence psychomotor performance in referees? A pilot study

I. Abstract:

Background: Decision-making (DM) is an important element of referees' performance. Any research on referees in field-based studies involving real matches has potential to influence actual performance. This could be detrimental to performance and influence competitive match outcome so researchers must be sure any research/intervention does not impair referee performance before applying it in a real match situation. The aim of this pilot study was to determine whether undertaking a 10- min Psychomotor Vigilance test (PVT) before a match would influence referees' cognitive performance, especially decision-making.

Methods: Twelve qualified football referees (mean ± SD: age 32.8 ± 7.4 years; height, 174.7 ± 7.9 cm; weight 75.9 ± 10.8 kg), from the local area (Kent County FA), aged between 18-45 years, volunteered to take part. Referees were required to visit the laboratory twice (PVT and control trial). During each visit they undertook a referee decision test (FIFA Quiz) twice (separated by 60 min). In the PVT condition referees completed the 10-min PVT immediately after each FIFA Quiz. In the control condition all procedures were the same except without the PVT. Mood questionnaires (BRUMS) were also completed pre- and post- decision-making tests for both trails.

Result: Two-way repeated measures ANOVA found no significant effect of condition (F = 0.449, p = 0.517) and time (F = 0.000, p = 1.000), or condition × time interaction (F = 0.388, p = 0.546) for decision-making (FIFA test) score. ANOVA (2-way) found no significant effect of condition (0.049, p = 0.829) or condition × time interaction (F = 0.573, p = 0.716), whereas there was difference in time (F = 5.528, p = 0.001) for the 10 min PVT (RT: 244.1 ± 9.2 vs 243.4 ± 7.6 ms). Similarly, Friedman's test found no significant difference between pre- and post for BRUMS results (tension, depression, anger and confusion), respectively χ^2 = 3.03, p = 0.386, χ^2 = 3.00, p = 0.392, χ^2 = 3.00, p = 0.392, χ^2 = 0.45, p = 0.928 and χ^2 =2.76, p = 0.429, as well as there was no statistically significant main effects of condition (F = 0.40, p = 0.845) and time (F = 0.35, p = 0.564), or condition × time interaction (F = 0.88, p = 0.368) observed for fatigue (BRUMS).

In conclusion: The present study found that undertaking the Psychomotor Vigilance test for 10 min did not affect referees' decision-making or cognitive performance. Hence, the 10- min PVT can be safely used with referees before real competition/in the field.

II. Introduction:

Cognitive performance for athletes is a significant feature of performance. The referee is a main element of the game and they are required to maintain their concentration throughout the whole game, as referees' decisions may influence the result of the game (Catteeuw, Helsen, Gilis and Wagemans 2009). Actually, estimating cognitive performance before and after actual games is important in understanding factors that may influence decisions, and to gain insight into whether this aspect of performance decreases after a match. This might indicate if cognitive function decreases in the latter parts of a match, which could help to explain the reduction in physical and mental performance (e.g. correct decisions) often observed in the latter stages of matches. To fully answer this question it would be optimal to assess cognitive performance during the match but it is impossible to do this via direct measures of cognitive function, such as cognitive function tests, in real matches. It is possible to assess aspects of referees performance that are influenced by cognitive functions (e.g. decision making, proportion of correct/incorrect decisions) as a compromise or surrogate, although there are many other factors that may also be involved in such 'performance' outcomes, and this fact must be kept in mind. However, in order for a gold standard measure of cognitive function to be applied in real performance situations (e.g. a match) researchers are limited to applying such tests before and after the actual match. Evaluating referees' cognitive function is of wide interest and there are several types of cognitive tests, such as Stroop tasks, the PVT and AX-continuous performance test (AX-CPT) are available. Mental fatigue is defined as reduction of cognitive performance during or after prolong periods of physical and cognitive activity (Boksem and Tops 2008; Marcora, Staiano and Manning 2009). It was observed that incorrect decisions by referees occur more when fatigued (Catteeuw, Gilis, Wagemans, *et al.* 2010b; Ager 2015) but there is not much research on the effects of mental fatigue on referees' performance.

Mental fatigue can be caused by prolonged cognitive tests, such as the Stroop test (30 min) (Pageaux *et al.* 2014) and that this mental fatigue task is associated with decreased technical ability of football players (Badin *et al.* 2016). More recently, a study of Badin *et al.* (2016) on football players used the Stroop Task (30 min) to examine the effects of mental fatigue on cognitive performance and technical ability and this reported that mental fatigue negatively influenced players' technical performance. It is likely therefore that mental fatigue also has an impact on referees' cognitive performance but there is a lack of research on this.

Therefore, when assessing referees' cognitive performance before real matches or competition (as the baseline point of comparison), it is important to consider the potential for the tests themselves to induce mental fatigue and negatively impact performance in the subsequent match. The 10-min PVT is a cognitive function test that is an extensively recognised measure of neurobehavioral performance and cognitive functioning (Lamond, Dawson and Roach 2005; Doran, Van Dongen and Dinges 2001; Seicean *et al.* 2011; Jewett *et al.* 1999) that has been widely used in sport science context (Suppiah, Low and Chia 2016; Ballester *et al.* 2015). The 10-min PVT is extremely suited for laboratory studies but valuable practical insight can be gained from using it to determine the way that actual matches affect cognitive function in referees. Referees have an extremely important role in the match and they must maintain attention, and cognitive performance, throughout the match in order to implement the rules of the game correctly and manage the match (Pietraszewski *et al.* 2014). Therefore, studying how their PVT performance is affected by a match is particularly important, especially for referees who are officiating multiple games on the same day (a common occurrence in competitive Futsal tournaments or leagues). As the PVT itself can be considered cognitively demanding there is potential for it to influence subsequent physical performance and decision-making and hence to have negative effects on performance parameters that would be relevant to referees (indeed, it is suggested that football players should avoid mental fatigue prior to real matches or during competition as it may negatively impact performance (Badin *et al.* 2016) which may also be relevant for referees.

Although it is unlikely that a single 10 min PVT test with 60 min rest before a match will be sufficient to cause mental fatigue and induce such negative effects it would be prudent to test this experimentally before applying it in a real match situation. Thus, it is essential to determine whether undertaking the 10 min PVT has any effect on referees' subsequent cognitive performance, especially decision-making before using this test before real matches. The aim of this pilot study, therefore, was to determine the effects of undertaking the 10 min PVT on subsequent decision-making in order to determine it safety for future use in field-based research studies before real matches.

III. Methods:

Participants:

Twelve (12) qualified football referees (mean ± SD: age 32.8 ± 7.4 years; height, 174.7 ± 7.9 cm; weight 75.9 ± 10.8 kg), from the local area (Kent County Football Association [KCFA]) volunteered to participate in this study.

Study Design:

All methods and experimental procedures were approved by the University of Kent, School of Sport & Exercise Sciences (SSES), Research Ethics and Advisory Group (REAG) (Appendix 1). In addition, prior permission was granted by FIFA (Appendix 3) to use the FIFA Quiz (which is available online) in this research (FIFA 2016a).

Testing took place on a non-match (rest) day and the participants were required to come to the SSES at the University of Kent on 2 separate occasions (at the same time of day).

After agreeing to participate referees received a link to an online version of the PVT (http://www.sleepdisordersflorida.com/pvt1.html) and were asked to practice this in their own time, as a way of familiarisation with the test and how the test works. They then attended SSES on 2 separate occasions to undertake one of two trials (control or PVT conditions) in a randomised order.

PVT condition: The participants undertook a 2 min familiarisation to the PVT then rested for 30 min. They were then required to complete a referee decision test, which required the viewing of 20 clips of football incidents on a laptop (Samsung 15.6 LED Screen, Model; 300E5EV/300E4EV/270E5EV/270E4EV) and then making a judgement on the correct outcome (refereeing decision), from a list of options (no foul, indirect free kick, direct free kick, penalty kick, no card, yellow card and red card). They had to give their decision/answer within 10 seconds. This is a standard part of the FIFA referees' exam. This served as the baseline (pre-test) measure of refereeing performance. The participants then completed the 10- min PVT and then rested for 60 min (similar to their normal match preparation period) before completing the FIFA test again (post-test) to determine whether their performance had been affected. They then completed the 10-min PVT test one more time to see whether these measures had been affected by the PVT test undertaken 1 hour earlier (see figure 5.1).

Control condition: This was identical to the PVT condition except there were no PVT tests (only the FIFA clips test: at the equivalent of pre-test and post-test time points) (see figure 5.1). This was to establish if performance on this test changed when it was done twice with a period of rest in between. A short mood questionnaire (Brunel Mood State (BRUMS) (Appendix 4) was completed pre- and post- FIFA test).

Figure 5.1: The design of the pilot study for both visits

Measures:

Decision-making by FIFA Quiz DVD:

Men's Competitions in 2014 – Analysis of Match Situations: FIFA Quiz:

FIFA Quiz used pre- and post for both visits (control or PVT conditions). The FIFA Quiz is used to test referees and as method to educate and develop referees' understanding of laws of the game. Basically, this test has used in some literature (MacMahon *et al.* 2007; Gallardo, Iglesias and Quintana 2009; Armenteros *et al.* 2016).

Description: This DVD includes 125 "fouls and misconduct" match situation clips for analysis, 37 "match management" clips, 32 "match official technique" clips and 28 "offside" clips, selected from the following tournaments: FIFA World Cup Brazil 2014.

A random selection of 20 clips are shown form the possible 125 and the referees are required to answer the question "What decision should the referee take in the following situation?"

For each question they are given 10 seconds to answer and must select an answer from a choice of option as shown in Figure 5.2. This test cannot be paused and they cannot change an answer once it is entered. If they skip a question it is counted as wrong answer. They are not able to go back to a skipped question. For every question they must give an answer for both the restart and also if there should be a card given for the situation. Their score is visible after they click on an answer after seeing each video. To pass the FIFA test referees must score at least 15 correct answers (FIFA 2016a) and the test duration was ranged from 12 to 15 min.

Reliability analysis was performed for the FIFA quiz because it has never been used in a research setting like this before in order to give a benchmark for whether or not a change/difference in test scores was meaningful and also to confirm consistency of measurements when made on different days. Calculations were performed for limits of agreement (Bland and Altman 1986) coefficient of variation (CV) and intraclass correlation coefficients (Hopkins 2001). Reliability of FIFA test decision-making performance performed on two separate days gave a coefficient of variation (for percentage correct decisions) of 3.8% (<5% desirable, Hopkins 2000); limits of agreement ± 3.02% and the intraclass correlation coefficient was 0.79 (high/good, Atkinson and Nevill 1998).

Figure 5.2: Screenshot of FIFA Quiz answer slide. (FIFA 2016a)

The Psychomotor Vigilance test (PVT) Procedures:

The PVT is a cognitive function test and a sustained attention task that is an extensively recognised measure of neurobehavioral performance and cognitive functioning (Lamond, Dawson and Roach 2005; Doran, Van Dongen and Dinges 2001; Seicean et al. 2011; Jewett et al. 1999) that has been widely used in Sport Science context (Suppiah, Low and Chia 2016; Ballester et al. 2015). The requirement of the PVT is to respond to the visual stimulus (Dinges and Powell 1985). The 10 min PVT (Figure 5.3) was conducted using a portable electronic device (PVT-192-PVTCommW/REACT Software: PVTCommW version 2.61, United States). For familiarisation, referees were asked to participate in an online version of the PVT (http://www.sleepdisordersflorida.com/pvt1.html#responseOut) in their own time in advance of the first study visit. Tests were conducted in a quiet area with even lighting and a comfortable place for the subject to sit and hold the PVT-192. The following explanation was provided to subjects:

"*In this test, subjects are required to attend closely to a stimulus window and to press the response button with the thumb of the dominant hand (by pressing either the right or the left push button) as soon as a red stimulus counter appears on the screen, making an effort to keep response times as short as possible throughout the task, but not to press before the stimulus appears (which will yield a false start warning on the display). The stimulus, will occur randomly at intervals from 2 to 10 seconds*".

The display was a digital counter (displaying milliseconds) that appeared in red in a light-emitting diode (LED) window located on the device. The counter increased (in milliseconds) until the response button was pushed. This stopped the counter and displayed the reaction time to the subject. In brief, this test involves subjects responding to a visual stimulus appearing on a screen as quickly as possible, by pressing a button. They must press the button as soon as the stimulus appears and the device will measure how quickly they are able to respond.

Ambulatory Monitoring, Inc. P.O. Box 609

731 Saw Mill River Road.

Ardsley, New York 10502-0609

Phone: 800-341-0066 or 914-693-9240

Fax: 914-693-6604

Figure 5.3: The 10 min PVT

The Brunel Mood Scale (BRUMS):

A short mood questionnaire (BRUMS) (Appendix 4) was completed pre- and post- FIFA test). The BRUMS questionnaire (Terry, Lane and Fogarty (2003)) was used to assess current mood (‘‘How do you feel right now?’’) on a 24-items questionnaire, which provides scores for six subscales: tension, anger, confusion, depression, fatigue and vigour. Participants rate responses on a 5-point Likert scale (0 = not at all, 1 = a bit, 2 = moderate, 3 = enough; 4 = extremely), with a completion time of approximately 1 to 2 minutes. The items on each subscale are:

• Anger (annoyed, bitter, angry, bad-tempered);

• Confusion (confused, muddled, mixed-up, uncertain);

• Depression (depressed, downhearted, unhappy, miserable);

• Fatigue (worn out, exhausted, sleepy, tired);

• Tension (panicky, anxious, worried, nervous);

• Vigour (lively, energetic, active, alert).

Statistical Analysis:

All statistics procedures were performed using SPSS (23 Amonk, NY: IBM Corp). All data are presented as means ± standard deviation (SD) and significance was accepted at $P < 0.05$ for all the statistical tests.

Two-way repeated measures analysis of variance (ANOVA) was used to compare the pre- to post-test changes between conditions (control and PVT) in decision-making performance (FIFA test) and BRUMS parameters (fatigue), as well as among the 10 min PVT. Other PVT performance measurements were also compared between pre- and post-test time points within the PVT condition using paired t-tests when parametric (PVT "ms" and slowest and fastest) assumptions were met. When the data were not normally distributed (and could not be normalised with transformations) non-parametric tests were used. Friedman test was used for BRUMS tension, depression, anger, vigour and confusion and Wilcoxon matched-pairs test was used for PVT Total Errors, Lapses, and Lap (SQR XFRM).

IV. Result:

Decision-making (FIFA Quiz):

The 2-way ANOVA (2 conditions: PVT vs Control × 2 time points: pre and post-test) showed that there were no significant main effects of condition ($F = 0.449$, $p = 0.517$), time ($F = 0.000$, $p = 1.000$), or condition × time interaction ($F = 0.388$, $p = 0.546$) for correct decision scores (percentage correct) in the decision-making (FIFA) test (see Table 5.1).

Table 5.1: Number of correct decision on FIFA quiz

Tests of Within-Subjects Effects (ANOVA)			
Control -pre	Control-post	With PVT-pre	With PVT-post
72.5 ± 7.8%	**71.3 ± 4.8%**	**72.9 ± 8.6%**	**74.2 ± 12.6%**
Source	**df**	**F**	**Sig.**
Condition	1, 11	0.449	0.517
Time	1, 11	0.000	1.000
Condition × Time	1, 11	0.388	0.546

Values are mean ± SD (n=12). Statistical analysis values (Two way Repeated measured ANOVA (F, p) show correct D.M comparisons between pre and post for both visits (control and PVT visit) (F when parametric tests used).

The 10 min PVT:

Within the PVT trial, there was also no significant difference in the overall 10 min PVT mean reaction time between the pre and post time points (244.1 ± 9.2 ms pre- vs 243.4 ± 7.6 ms post, $p = 0.829$). Two-way repeated measures ANOVA (2 trials: PVT test 1 (pre) vs PVT test 2 (post) × 10 time points: minutes 1-10, respectively, during the PVT test) found no statistically significant main effects of trial ($F = 0.049$, $p = 0.829$) or trial × time interaction ($F = 0.573$, $p = 0.716$). There was a main effect of time, showing the normal temporal pattern within the 10 minute PVT ($F = 5.528$, $p = 0.001$) but this did not differ between the two tests (Figure 5.4). Therefore, there was no significant ($p > 0.05$) difference in pre- and post- PVT. It was also observed for other PVT measurements (Total Errors, Lapses ''RT > 500ms'', Lap ''SQR XFRM'', Mean S RT. Mean F RT) there were no significant ($p > 0.05$) differences: as shown in Table 5.2.

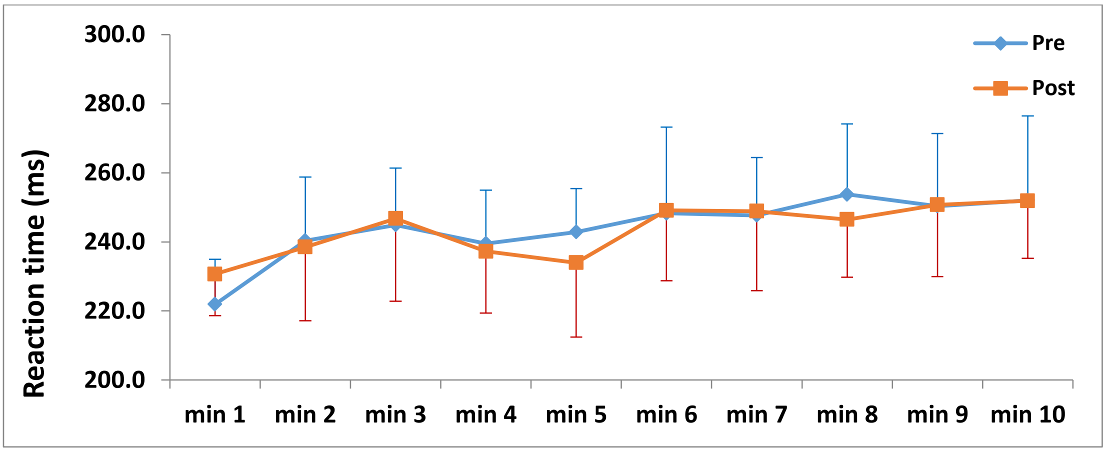


Figure 5.4: Psychomotor vigilance test reaction time (PVT) (pre and post) results

Table 5.2 - Psychomotor vigilance test (PVT) measurements results:

PVT measures	Pre	Post	Statistical analysis values (t/z, p)
Total Errors	1.1 ± 1.1	0.8 ± 0.8	z = -0.60, p = 0.546
Lapses (RT > 500ms)	1.2 ± 1.0	0.7 ± 0.8	z = -1.29, p = 0.196
Lap (SQR XFRM)	1.9 ± 1.0	1.6 ± 1.1	z = -1.29, p = 0. 196
Slowest 10% (1/RT)	2.6 ± 0.4	2.8 ± 0.2	t = -1.38, p = 0.194
Fastest 10% (1/RT)	5.4 ± 0.4	5.4 ± 0.5	t = 0.28, p = 0.781

Data are presented as mean ± SD (n=12). RT refers to mean reaction time (Mean RT). Total Errors. Lapses (RT > 500ms). Lapses (SQR XFRM). Mean S RT (1/ slowest 10% RT). Mean F RT (fastest 10% RT).

Statistical analysis values (t/z,p) show comparisons between pre- and post (t when parametric, z when non-parametric tests used).

BRUMS:

Friedman's test found no significant difference between pre- and post for BRUMS results (tension, depression, anger and confusion), respectively χ^2 = 3.03, p = 0.386, χ^2 = 3.00, p = 0.392, χ^2 = 3.00, p = 0.392, χ^2 = 0.45, p = 0.928 and χ^2 =2.76, p = 0.429, as well as there was no statistically significant main effects of condition (F = 0.40, p = 0.845) and time (F = 0.35, p=0.564), or condition $^\times$ time interaction (F=0.88, p=0.368) observed for fatigue (BRUMS) results as shown in Table 5.4 and Figure 5.5 & 5.6.

Table 5.3 – BRUMS scores pre- and post for both conditions

	Mood Q control		Mood Q with PVT		Statistical analysis values (χ^2/F, p)
	pre	post	pre	post	
Tension	0.9 ± 0.7	0.8 ± 0.8	0.9 ± 1.0	0.4 ± 0.7	χ^2 = 3.03, p = 0.386
Depression	0.2 ± 0.4	0.5 ± 0.7	0.4 ± 0.9	0.3 ± 0.9	χ^2 = 3.00, p = 0.392
Anger	0.1 ± 0.3	0.4 ± 0.9	0.1 ± 0.3	0.1 ± 0.3	χ^2 = 3.00, p = 0.392
Vigour	8.8 ± 2.9	7.9 ± 2.8	7.9 ± 2.6	8.3 ± 2.9	χ^2 = 0.45, p = 0.928
Confusion	0.3 ± 0.5	0.8 ± 1.5	0.3 ± 0.5	0.1 ± 0.3	χ^2 =2.76, p = 0.429
Fatigue	3.5 ± 1.4	3.0 ± 1.5	3.2 ± 1.6	3.3 ± 1.1	Condition: F = 0.40, p = 0.845 Time: F = 0.35, p=0.564 Condition $^\times$ time: F=0.88, p=0.368

Data are presented as mean ± SD (n=12)

Statistical analysis values (Friedman (χ^2)/F, p) show comparisons between both conditions at pre and post-match (F when parametric, χ^2 when non-parametric tests were used).

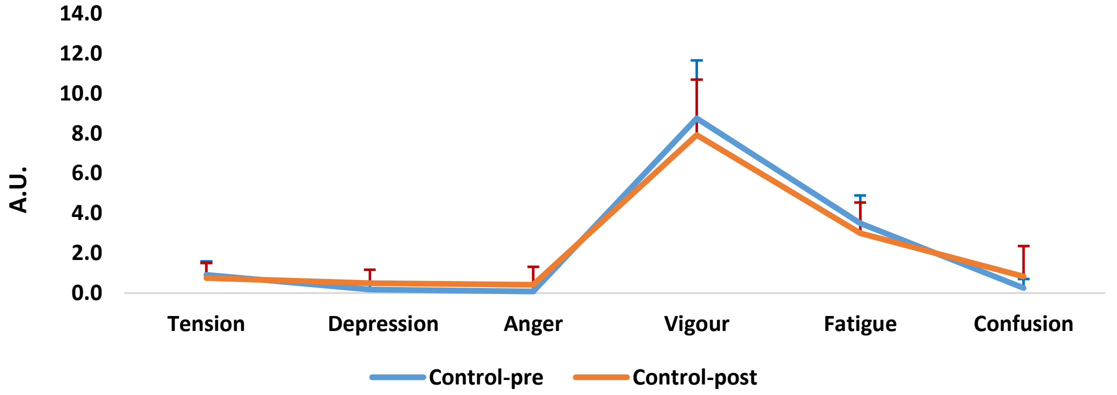


Figure 5.5: BRUMS scores (Arbitrary Units, A.U.) pre- and post for control trail

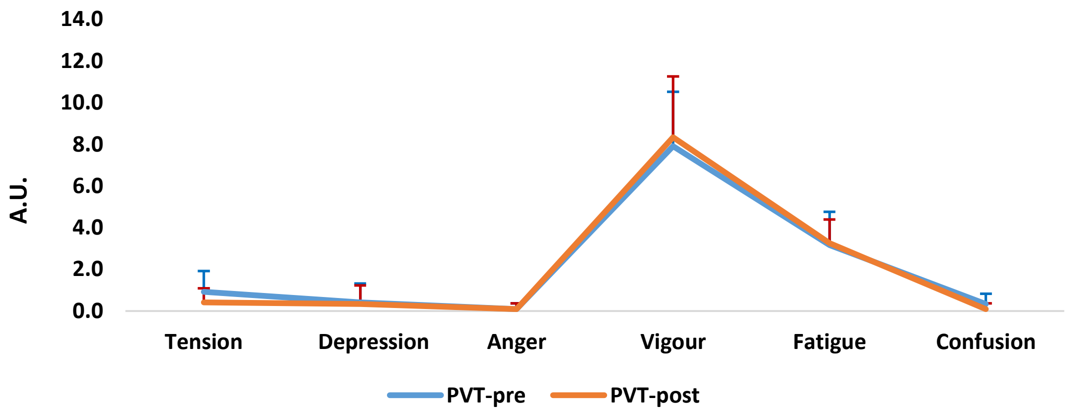


Figure 5.6: BRUMS scores (Arbitrary Units, A.U.) pre- and post for PVT trail

V. **Discussion:**

The aim of this pilot study was to determine whether undertaking the 10-min Psychomotor Vigilance test (PVT) has any effects on referees' decision-making (assessed by the FIFA quiz DVD) or cognitive performance (assessed by the PVT) 60 min later. Our results show that the 10 min PVT did not influence referees' cognitive or decision making performance. These results show that there was no difference in referees' performance caused by undertaking the PVT. It has been reported previously in the literature that there is no significant impact of cognitive tasks on decision-making (Blais, Thompson and Baranski 2005). However, a study of Badin *et al.* (2016) on football players reported that a cognitive task (Stroop test) of 30 min duration influenced technical ability. In addition, Marcora, Staiano and Manning (2009) showed that 90 min cognitive performance task (AX-CPT) negatively influenced physical performance. In the present study, there was also no difference in reaction time for the actual PVT results between pre- and post-test in the PVT condition, providing further support that the 10 min PVT does not negatively influence cognitive function 60 min later. There was also no difference in BRUMS scores between pre- and post- test in either condition (PVT or control).

Possible reasons for non-significant differences between pre- and post- times for decision-making, PVT, or BRUMS is because the demands of undertaking the test were minimal and did not tax the referees cognitively, likely due to the shorter duration of the test (compared to previous research with mentally fatiguing tasks). Therefore, the 10 min PVT could be used to test athletes before an actual match. The current study used the 10 min PVT so it is possible that longer tests (as observed in the study of Badin *et al.* 2016 on football players), or repeated tests, might increase demand and have different effects on referees' performance. Furthermore, the study only tested the utility of completing the PVT 60 min before reassessment. It is possible however that performance would be reduced with a shorter period between tests. It is clear that some cognitive demands (especially if combined with physical demands) can impact subsequent cognitive performance (Marcora, Staiano and Manning 2009), but the findings of this study show that the administration of a single PVT 60 min before the match is unlikely to compromise referees' performance (decision-making ability). The results also suggest good reliability of the FIFA DVD quiz (as the results of reliability tests in the above [method: *Decision-making by FIFA Quiz DVD*] confirmed the consistency of measurements when made on different days) and support the utility of using it to assess practically relevant cognitive performance/decision-making in referees in future research.

Limitations

A limitation of the present study was the use of Football referees since this was to be applied to a study with Futsal referees. This was due to a lack of available Futsal referees able to visit the lab for this pilot study. However, the primary aim was methodological to ensure no adverse effects from undertaking the tests. Nevertheless, it would be beneficial for future studies to confirm this in Futsal referees. It would also be useful to study different levels (e.g. experience, expertise) since they may influence the outcome and would allow us to establish, for example, whether lower level or less experienced referees are more susceptible to negative effects, from a 10 min PVT, on subsequent performance. It would also be useful for future studies to investigate different durations or repetitions (e.g. repeat the PVT serially with various rest durations in between), as a dose-response type study that could inform future research (e.g. to understand how many PVTs are required before negative effects are seen, and hence how many it would be safe and ethical to administer before matches in future studies).

Conclusion

In conclusion, the present findings show that the 10 min PVT did not affect referees' decision-making and thus undertaking the 10-min PVT 60 minutes prior to a game is unlikely to affect referee decision-making performance and can be safely used with referees before real competition/in the field to assess psychomotor performance and cognitive function.

Chapter 6

The effect of a competitive match on Psychomotor Vigilance in Futsal Referees

I. Abstract:

Background: Referees' physical and cognitive performance are important for successful officiating in team sports. There is a lack of research on cognitive performance in referees in general, and none in Futsal. The aim of the present study was to assess referees' performance on the Psychomotor Vigilance Test (PVT) before and after competitive Futsal matches during the FA National Futsal League 2015/16.

Methods: Fourteen Futsal referees (mean ± SD: age 34.3 ± 10.0 years) from the FA National Futsal Group were included. The referees were required to undertake a 10-min PVT at 60 mins before the match kick-off time (pre) and immediately after matches. They also completed the Brunel Mood Scale (BRUMS) questionnaire before the pre-match PVT and after the post-match PVT.

Result: Data were analysed by paired t-tests comparing pre- and post-match results. There was a significant difference in BRUMS parameters vigour (9.5 ± 2.5 pre- vs 6.3 ± 2.4 post-match, $p = 0.001$) and fatigue (1.4 ± 1.3 pre- vs 5.6 ± 3.1 post-match, $p < 0.001$). However, PVT performance was significantly improved (mean reaction time 248.3 ± 26.2 ms pre- vs 239.7 ± 22.4 ms post-match, $p = 0.023$).

In conclusion: The present results show, contrary to our initial hypothesis, that psychomotor performance is improved as opposed to decreased after a single match. The post-match improvement suggests that exercise can acutely enhance cognitive performance, which could be used to inform warm-up practices (e.g. optimal duration and intensity) geared towards optimising cognitive performance of referees during matches.

II. Introduction:

Futsal is one of the official games established by FIFA and is played between two teams consisting of five players per team. Futsal is a high-intensity intermittent team sport with changes in activity every 3.28 seconds (Doğramacı and Watsford 2006). It is considered to be quick and demanding (both physically and mentally) for both players and referees (Hermans and Engler 2010). Weston *et al.* (2012) indicated that mental performance is important in refereeing but there are limited studies investigating referees' cognitive performance and decisions. In addition, the physiological demands of the referee is equally important but, as mentioned in Chapter 3, there is also limited research and understanding of this specifically in relation to referees in a Futsal game (Castagna et al. 2009).

There are many studies (Adnan, Muzayin and Sulaiman 2013; Makaje *et al.* 2012; Da Silva, Fernandes and Fernandez 2011; Gray and Jenkins 2010; Krustrup *et al.* 2009; De Oliveira *et al.* 2008; Mallo *et al.* 2007; Krustrup, Mohr and Bangsbo 2002; D'ottavio and Castagna 2001a; Catterall *et al.* 1993) that have explored activity analysis and physiological demands in detail for football referees, and also investigated fitness and the referees' performance (Castillo *et al.* 2016; Adnan, Muzayin and Sulaiman 2013; Weston *et al.* 2009; Casajus and Castagna 2007; Castagna, Abt and D'Ottavio 2005; Castagna, Abt and D'ottavio 2002) but there are only two studies on Futsal (Rebelo *et al.* 2011; Dixon 2014b). Futsal and football are very different in terms of physiological profile and demands on referees and the studies on football should not be assumed to be relevant of Futsal referees. Furthermore, it is important to consider factors such as cognitive performance of referees as cognition has an important role in decision-making. There are a few studies (Krustrup and Bangsbo 2001; Helsen and Bultynck 2004) that have examined activity profile and physiological strain of referees during games but there is no research on perceptual-cognitive factors or cognitive performance in referees, which is suggested to be of key importance (Weston *et al.* 2012).

The 10-min PVT is widely used to assess neurobehavioral performance and cognitive functioning (Lamond, Dawson and Roach 2005; Seicean *et al.* 2011; Jewett *et al.* 1999). The 10-min PVT is extremely suitable for laboratory studies (Dorrian, Rogers and Dinges 2005; Dinges *et al.* 1997; Dinges and Powell 1985; Tilley and Wilkinson 1984) and has been used extensively in sport and exercise contexts (e.g. Suppiah, Low and Chia 2016; Ballester *et al.* 2015; Klass *et al.* 2012). As such, the PVT can provide valuable practical insight into the effects of competitive matches on cognitive function in referees.

The use in field studies before and after real matches has the potential to provide further insight into the effects of actual real-life performance that may have more practical relevance. In chapter 5 it was shown that it is feasible to use the 10-min PVT shortly before an actual match without having any negative effects or carry over effects on referee cognitive performance, meaning it suitable to use before actual competitive matches.

Referees play an extremely important role in the match and they must maintain attention and cognitive performance throughout the match in order to implement the rules of the game correctly and manage the match. This cognitive demand, in combination with the physical demands and fatigue might be expected to contribute to reduced cognitive performance. Any changes in cognitive performance during a match/resulting from a match have the potential to influence referees' performance (such as decision-making) in the latter stages of a match or in subsequent matches if officiating multiple games on the same day (a common occurrence in competitive Futsal tournaments or leagues). Tomporowski and Ellis (1986) have shown that physical activities significantly impact upon cognition and the acute effects on cognitive performance is influenced by the nature of the exercise. Cognitive performance may be enhanced or decreased depending on the timing of assessment, fitness/training status of the athlete and intensity and duration of the exercise (Lambourne and Tomporowski 2010; Del Giorno *et al.* 2010; Tomporowski and Ellis 1986).

Therefore, it is important to investigate cognitive performance changes after a competitive match for referees to better understand the effects of a competitive match on key aspects of referees' performance. The aim of this study, therefore, was to determine whether PVT performance changes after, compared to before, a competitive match in Futsal referees. It was hypothesized that referees' PVT performance would deteriorate post-match as a result of physical and/or mental fatigue induced by the match.

III. Methods:

All methods and experimental procedures were approved by the University of Kent, School of Sport & Exercise Sciences (SSES), Research Ethics and Advisory Group (REAG) (Approval reference No: 100_2014_2015) (Appendix 1).

Participants:

Fourteen male Futsal referees aged between 18-52 years (mean ± SD: age 34.3 ± 10.0 years; height, 178.2 ± 8.9 cm; weight 82.7 ± 13.3 kg) volunteered to take part in the study. Participants were recruited from the FA National Futsal Group (FNFG) and the study took place at the FA National Futsal League 2015/16 season, with permission from the FA (Appendix 5). All referees had more than 5 years refereeing experience at the time of testing. Prior to participation, all participants received a participant information sheet at least 24 hours before giving their written informed consent to take part.

Study Design:

Before commencing this study (with official competitive matches in which referees performance could impact on the match outcome) a pilot study was first conducted to ensure that undertaking the 10-min PVT before the match would not adversely affect their cognitive performance in the match (Chapter 5). The results of the pilot confirmed that the completion of a 10-min PVT did not influence referees' cognitive or decision-making performance. After agreeing to participate, referees were sent a link to an online (http://www.sleepdisordersflorida.com/pvt1.html#responseOut) practice version of the PVT, and instructed to practice the PVT at home for familiarisation; compliance was verbally checked and confirmed by each referee on the match testing day. In addition further familiarisation was performed (for 2-min, using the same portable equipment to be used in the main trial) on the match day. Referees were asked to arrive approximately 1.5 h prior to kick-off time (they are usually instructed by the FA to arrive 1 h before, so the extra 30 min allowed the extra time necessary for research participation without impeding their normal preparation). They first completed the 2 min familiarisation of the PVT test (to consolidate the prior familiarisation and also to familiarise them with the specific portable equipment to be used for the actual study test). They then had a 30 min rest before they completed the 10-min PVT at 60 min before the match kick-off time. They were then free to undertake their normal warm-up and preparation routine (usually

45 min to 30 min pre-match). After they completed the warm-up, they were fitted with the HR monitor. They then completed the match as normal before repeating these measures as soon as convenient for them after the match (commencing within 4 min). There were asked to express session RPE 10 min after the 1st half and after the final PVT (> 10 min and < 30 min post-match).

Measures:

Heart rate:

Heart rate was recorded continuously through the match every 1 s for the first and second halves using a telemetric chest strap and wrist watch receiver (Polar Vantage NV HR monitor) in the same way as was done in Chapter 4 (section Heart rate).

Session Rating of Perceived Exertion (RPE):

Session RPE for the first and second half was expressed 10-15 min after exercise using the method of Foster *et al.* (2001) as detailed in Chapter 4 (see section *Session Rating of Perceived Exertion).*

The Brunel Mood Scale (BRUMS):

Mood questionnaires (BRUMS) were recorded before PVT (pre-match) and post PVT after the game (post-match) as detailed in Chapter 5 (see section *The Brunel Mood Scale).*

PVT Procedures:

The PVT was conducted using a portable electronic device. The counter increased (in milliseconds) until the response button was pushed as detailed in Chapter 5 methods section (*PVT Procedures*). This stopped the counter and displayed the reaction time to the subject.

Statistical Analysis:

All statistics procedures were performed using SPSS (23 Amonk, NY: IBM Corp). All data are presented as means ± standard deviation (SD) and significance was accepted at $P < 0.05$ for all statistical tests.

Two-way analysis of variance (ANOVA) was used to compare the 10 min PVT pre- and post-match (2 factors: condition has 2 levels and is used to differentiate pre-match and post-match tests; time has 10 levels comprised of the average score for each 1 min segment in the 10 min PVT test). Paired sample t-tests were performed for comparison of overall mean PVT reaction time between pre and post-match (Reaction Time (RT), Slowest 10% and Mean RT Fastest 10%), BRUMS fatigue (pre and post-match) when parametric assumptions were met.

However, when the data were not normally distributed (and could not be normalised with transformations) non-parametric tests were used (Wilcoxon matched-pairs test) for BRUMS tension, depression, anger, vigour and confusion (pre- and post-match), HR (First and second halves) and RPE (half-time and post-match).

IV. Result:

Two-way repeated measures ANOVA showed a significant main effect of condition (pre-match vs post-match: $F = 6.65$, $p = 0.023$) and time ($F = 3.93$, $p = 0.009$) but no condition × time interaction ($F = 0.64$, $p = 0.761$): see Figure 6.1. There was a significant difference in the overall 10 min PVT mean reaction time pre- and post-match (248.3 ± 26.2 ms pre- vs 239.7 ± 22.4 ms post-match, $p = 0.023$). There was no significant difference for other PVT results (Total Errors, Lapses [RT > 500ms], Lapse-XFRM [square root transformed], Slowest 10% [1/RT] and Fastest 10% reaction times) as shown in Table 6.1.

In terms of comparison between referees' experiences (more than 10 years vs less than 10 years), Two-way repeated measures ANOVA showed there was no significant difference main effect of condition (pre-, post-match: $F = 0.88$, $P = 0.392$), time (across minutes: $F = 4.02$, $p = 0.101$), condition × time interaction ($F = 0.03$, $p = 0.874$). There was also no significant difference for Total Errors, Lapses, Lapse-XFRM, Slowest 10%, or Fastest 10% reaction times.

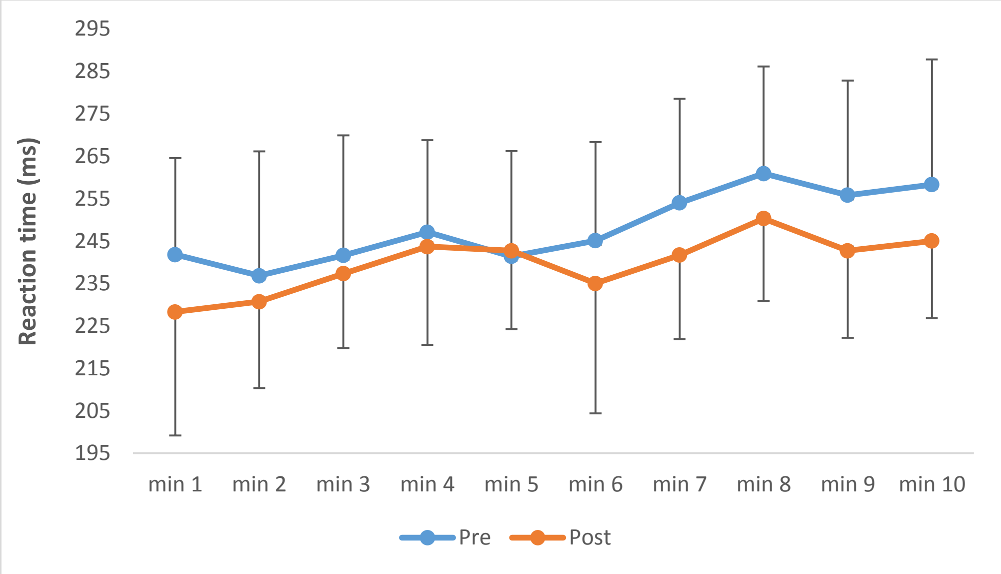


Figure 6.1: Psychomotor vigilance test reaction time (PVT) pre and post-match.

Table 6.1 - Psychomotor vigilance test (PVT) parameters pre and post-match:

PVT measures	Pre	Post	Statistical analysis values (t/z, p)
Total Errors	3.1 ± 4.8	3.8 ± 4.9	z = - 1.23, p = 0.127
Lapses (RT > 500ms)	0.8 ± 1.1	0.6 ± 0.8	z = - 0.33, p = 0.739
Lapse-XFRM	1.8 ± 1.1	1.8 ± 0.9	z = 0.00, p = 1.000
Slowest 10% (1/RT)	2.8 ± 0.4	2.9 ± 0.3	t = - 1.05, p = 0.309
Fastest 10% (1/RT)	5.3 ± 0.6	5.4 ± 0.5	t = -0.72, p = 0.482

Data are presented as mean ± SD (n=14). RT (mean reaction time, RT). Total Errors (in whole 10 min test). Lapses (RT > 500ms). Lapses-XFRM (Lapses square root transformed). Slowest 10% (1/ slowest 10% RT). Fastest 10% (fastest 10% RT).

BRUMS vigour and fatigue were significantly different post-match: vigour 9.5 ± 2.5 pre- vs 6.3 ± 2.4 post-match (p = 0.001), fatigue 1.4 ± 1.3 pre- vs 5.6 ± 3.1 post-match (p = 0.001) (see Table 6.2). There were no differences for any of the other BRUMS parameters (tension, depression, anger and confusion) as shown in Table 21, however there was a trend for Tension to decrease post-match (p = 0.053) (Table 21).

Table 6.2: BRUMS conditions pre and post-match

	BRUMS Q		Statistical analysis values (t/z, p)
	pre	Post	
Tension	0.7 ± 0.9	0.2 ± 0.6	z = - 1.93, p = 0.053
Depression	0.1 ± 0.3	0.2 ± 0.6	z = - 1.41, p = 0.157
Anger	0.2 ± 0.6	0.4 ± 0.6	z = - 0.70, p = 0.480
Vigour	9.5 ± 2.5	6.3 ± 2.4	z = - 3.18, p = 0.001
Fatigue	1.4 ± 1.3	5.6 ± 3.1	t = - 4.91 p < 0.001
Confusion	0.3 ± 0.6	0.2 ± 0.6	z = - 0.37, p = 0.705

Data are presented as mean ± SD (n=14)

Statistical analysis values (t/z, p) show comparisons between pre and post-match (t when parametric, z when non-parametric tests used).

The mean heart rate was 123.6 ± 20.3 bpm. Referees showed significant differences in heart rate (first half compared to second half) and session RPE in relation to the 1st vs 2nd halves, as shown in Table 6.3.

Table 6.3: Heart rate and RPE

Heart rate	First half	Second half	Statistical analysis values (z, p)
	125.6 ± 20.5	121.7 ± 20.8	z = -2.10, p = 0.035
RPE	Halt-time	Post-match	Statistical analysis values (z, p)
	3.0 ± 1.2	4.1 ± 1.0	z = -2.38, p = 0.017

Data are presented as mean ± SD (n=14)

Statistical analysis values (z, p) show comparisons between pre and post-match (t when parametric, z when non-parametric tests used).

V. Discussion:

To the best of our knowledge, this is the first study to assess perceptual-cognitive performance of Futsal referees following actual competitive matches. The main findings of the present study are that officiating a competitive Futsal match improved PVT performance. This differs to our original hypothesis as it was expected the combined physical and mental demands of the match to have negative effects on cognitive performance. Comparable results have been found in previous studies (Wiśnik *et al.* 2011; Chmura and Nazar 2010; Chmura *et al.* 1998) with football players in which of psychomotor performance was found to improve after different running activities (low and high intensity). The explanation given was that different exercise activities (low and moderate) activate CNS functions and thus psychomotor performance can be improved (Wiśnik *et al.* 2011). Therefore, it is likely that the combined physical and mental stress of the match in the present study was not sufficiently demanding to have negative effects on performance, and to the contrary may have been beneficial.

It has been shown that moderate intensity exercise enhances brain function and improves cognitive performance (Ellemberg and St-Louis-Deschênes 2010; Kashihara *et al.* 2009; Brisswalter, Callardeau and René 2002). This was suggested to be related to the effects of exercise on the central nervous system (CNS) and levels of neurotransmitters (Kashihara *et al.* 2009). In the present study the average heart rate (first half 125.6 bpm and second half 121.7 bpm) was lower than those reported in previous studies on Futsal (Rebelo *et al.* 2011; Dixon 2014a), and also considerably lower than the average HR values reported in study 1 (Chapter 4) of this thesis (1st half 151 bpm, 2nd half 145 bpm). This suggests that overall intensity (and physiological demand) was relatively low-moderate in the present study compared to others. It is likely that the acute effects of exercise are determined by the nature of the exercise, including intensity and duration (and thus the amount of fatigue experienced), (Brisswalter, Callardeau and René 2002; Kashihara *et al.* 2009; Ellemberg and St-Louis-Deschênes 2010; Lambourne and Tomporowski 2010; Chang *et al.* 2012). It was reported that after prolonged exercise (for 40 or 60 min), cognitive performance improved, even if fatigue symptoms appeared classically reported (Brisswalter, Callardeau and René 2002). In addition, in the review of Tomporowski (2003), it was indicated that the capacity for attention and cognition improved after prolonged exercise/aerobic exercise compared with pre-exercise. In contrast, several studies (Del Giorno *et al.* 2010; Tomporowski 2003) indicated that exercise did not improve cognitive function. Indeed, acute exercise could impair/decrease cognitive performance (Kashihara *et al.* 2009; Brisswalter, Callardeau and René 2002), so it seems the specific, relative demands of the exercise dictate the direction of effect on cognitive performance, and Tomporowski (2003) noted the complex nature of the relationship between exercise-induced arousal and cognitive performance. On the other hand, Elsworthy, Burke and Dascombe (2016) conducted a study on football and rugby referees in a laboratory and found that there was no difference between pre- and post-exercise for response times, even though their physical performance (total distance coverage) declined in the second half. It is possible that the referees self-select to reduce their work output (i.e. slower and/or less distance) when fatigued and this reduction in physical performance is protective against consequent decreases in mental performance and may explain differences compared to findings with exhaustive exercise or laboratory studies where total work or exercise intensity is externally controlled (e.g. fixed intensity to exhaustion) (Pageaux 2014).

The present results suggest that referees were able to maintain their cognitive performance over the course of a match, which could suggest resilience to negative effects of physical and mental fatigue. It could be that the actual physical demand was relatively low (i.e. their specific fitness was sufficient) so that the match was equivalent to moderate exercise, which is known to acutely enhance cognitive function (Brisswalter, Callardeau and René 2002). It is also possible that the referees were well trained and adapted (accustomed) to the demands of the match (including the cognitive demands) and so the match did not represent a significant challenge for them. Indeed, the fact that they have at least 5 years of experience mean that they may be well 'trained' for and resistant to these demands. Indeed, it has been shown that cognitively demanding training (e.g. Marcora, Staiano and Manning 2009) and elite status (Martin *et al.* 2016) are associated with resistance to the effects of physical and mental fatigue on both physical and cognitive performance, although these studies were not in referees. Additionally, in the present study referees may have self-selected lower intensities (and reduced work rate/distance covered/speed of movement) as they became fatigued as a protection mechanism which prevented any decrease in cognitive performance from occurring. This cannot be fully determined in the present study but the decrease in mean heart rate in the 2nd half lends at least some tentative support to this. It would have been useful to be able to assess cognitive performance at half time, or at regular intervals during the match (when fatigue levels may have been higher), but this is not feasible in a real match situation. Therefore, laboratory simulation studies may be useful to provide further insight on this area.

This study found that referees improved cognitive performance post-exercise. This could provide practical implications of relevance to pre-match strategies (e.g. warm-up) for optimising subsequent performance. However, since this was not a main objective of this study, it can only show that an increase was present pre- to post-exercise. Future studies should further explore the relationship to identify the optimal type (including duration and intensity) of exercise (or perhaps the minimal amount needed) for optimal benefit to cognitive performance.

Mood states results indicated that there was no significant difference between pre- and post-match findings in tension, depression, anger and confusion. However, increased fatigue and decreased vigour post-match fit the profile of mental and physical fatigue. However, in line with the results for HR and session RPE, these results suggest that the match was not as physically demanding as seen in previous studies (as discussed above). As such, if the matches were more demanding (as reflected by higher mean HR, session RPE and greater changes in relevant BRUMS scores) it is possible that PVT results would be adversely affected. It is only possible to speculate on this at present, and further study is required with more demanding matches and/or laboratory simulation studies with a higher overall exercise-intensity. It is also possible that the increased BRUMS fatigue scores expressed post-match (when psychomotor performance was improved) are just an expression of referees' perception due to the physical demands only (or an expectation that they should increase).

Limitations

A limitation of the present study is that the overall physical demand (indicated by mean HR and session RPE) was lower than that reported in other studies (including Study 1 [Chapter 4] of this thesis). The effects of more strenuous matches (and/or repeated matches on the same day) may differ to the findings of this study. Future research should seek explore this further by studying a variety of matches to cover a range of demands from easy to very intense and strenuous. This 'dose-response' effect could be further explored/validated with lab-based simulation studies also. Since there is some evidence that cognitively demanding training and elite status are associated with resistance to the effects of physical and mental fatigue (in other sports) it would also be useful for future research to compare referees of different levels and/or experience.

It is also a limitation that the PVT can only be administered before and after the match, as this might miss the most intense and demanding (or fatiguing) times during the match. It would not be practical or feasible to undertake additional PVTs during a real match but this would be possible in a simulated lab-based match or a 'friendly' match organised just for the purposes of a research study, in which it would be possible to stop the match for PVTs to be undertaken at various times during the game.

It was also not possible to video the matches in this study. If this was possible, much like study 1 of this thesis, it would allow further exploration of the relationships between changes in cognitive performance (e.g. PVT) post-match and decision making performance in the later stages of the match. This is an area that could be explored further in future studies.

Conclusion

In conclusion, the present findings were in opposition to the initial hypothesis that the PVT performance would decrease post-match, due to mental and physical fatigue. These results suggest that referees were able to maintain their cognitive performance over the course of a match even though perception of BRUMS fatigue increased and vigour decreased post-match.

This could be due to the relative demands (both physical and cognitive) being moderate (associated with enhanced function via activation of the CNS) and/or a high level of resistance to decrements in referees. The latter could be an innate characteristics of top level referees or something that develops with training/practice (since all referees had at least 5 years of experience). From a practical perspective, it is possible that this could be used to inform pre-match preparation (e.g. warm-up) with a view to optimising cognitive preparation/performance although further work is required to identify the optimal (and/or minimal) durations and intensities of exercise required to elicit this. The findings of the present study are applicable to single matches but it remains to be determined how cognitive performance is affected when officiating multiple matches in a single day or over consecutive days, which is common in many tournament situations in Futsal.

Chapter 7

Effect of mental fatigue on cognitive function and physiological responses to exercise in referees

I. Abstract

Background: Mental fatigue is a psychological phenomenon that is caused by prolonged and/or demanding cognitive activity. It is important to estimate factors that impair referees' performance especially in the second half of a football match. There is limited research on the potential effects of mental fatigue on both physical and cognitive performance of referees.

Methods: Twelve (12) active football referees aged between 18-45 years (mean ± SD: age 32.3 ± 10.0 years) were recruited from KCFA to take part in the study. The referees were required to visit the laboratory on three separate occasions: a familiarisation (visit 1) and two main trials (control and mental fatigue, visits 2 and 3). Referees were required to perform a 90 min intermittent treadmill protocol after 30 min of a Stroop task: either incongruent (mental fatigue condition) or congruent (control condition). They were required to undertake the FIFA video clip test (decision-making) at the beginning (during warm-up: 13 min) and end of exercise (last 13 min). Heart rate, RPE and blood lactate measures were recorded before, during and after exercise. They also completed the PVT before and after the Stroop task, at half time and post-exercise and the Brunel Mood Scale (BRUMS) before and after the pre-match PVT and after the post-match PVT.

Result: The mental fatigue condition caused a significant decrease in decision-making performance (correct decisions, beginning: 76.7 ± 7.2% decreased to end exercise: 64.6 ± 7.8%, $p < 0.001$) compared to no change in the control condition). The PVT performance was also significantly reduced post-Stroop test, at half time and post-exercise, but to a greater extent in the mental fatigue condition ($p < 0.05$).

In conclusion: mental fatigue had a negative impact on referees' cognitive performance during and after exercise. This may have implications for optimising referees' preparation and cognitive performance in real matches, which should be explored further.

VI. Introduction

In the field-based studies in the previous chapters, it was observed that referees activity levels (study 1) (and heart rate, study 1 and study 2) were reduced in the 2nd half compared to 1st half but cognitive performance improved post-match in the 3rd study (Chapter 6). This chapter aims to overcome some of the limitations discussed in the previous chapters by using a lab-based design in which relevant parameters (physical performance, physiological responses and cognitive performance) could be monitored more regularly during a standardised intermittent exercise protocol designed to simulate the physiological demands of team sports.

As football matches are 90 min in duration and Futsal matches typically last between 70 to 80 min, and requires sustained attention from the referee, it is possible that mental fatigue will occur, which can influence both physical and mental performance (e.g. Marcora, Staiano and Manning 2009; Pageaux 2014; Smith *et al.*, 2016a, 2016b). Recently Pageaux (2014) used the incongruent Stroop tasks to induce mental fatigue (compared to congruent Stroop task for control) and demonstrated that mental fatigue reduced endurance running performance.

Result of various studies (Weston *et al.* 2007; Krustrup and Bangsbo 2001; Da Silva, Fernandes and Fernandez 2008; Mallo *et al.* 2008; Weston, Drust and Gregson 2011; Catterall *et al.* 1993) have shown that referees performance is reduced in the second half of a football match. Most research suggests this to be related to accumulated (physical) fatigue and this could lead to incorrect decisions and thus effect on the outcome of the game. However, there is limited research on the potential effects of mental fatigue on both physical and cognitive performance of referees. This is of relevance because referees may be mentally fatigued at the beginning of a match if they have had a mentally taxing task in the period before, and/or they may suffer mental fatigue during the match due to the physical and cognitive demands of the game. There is limited research, however, to confirm that mental fatigue contributes significantly to the reduction of referees' performance in the second half, although it is suggested that mental fatigue could lead to incorrect decisions (Catteeuw, Gilis, Wagemans, *et al.* 2010b; Ager 2015).

It is difficult to investigate the factors that influence referees' decision-making during real matches as the required measurements would interfere with actual match performance and be logistically difficult. This was assessed in study 1 of this thesis (Chapter 4) using an expert panel to assess and rate referees' decision-making performance during competitive Futsal matches. However, this has limitations, in that every match is different and it is difficult (if not impossible) to compare different matches or investigate different conditions (e.g. mental fatigue) in a repeated measures design, whereby an appropriate control condition (in which all other demands are the same) is needed for comparison. For these reasons, well controlled laboratory studies that sufficiently represent (or mimic) match demands are desirable.

There are just two studies that have investigated decision-making for football officials in the laboratory (Taylor *et al.*, 2014; Watkins et al., 2014). The Taylor *et al.* (2014) study is the only one to date to examine football referees for two 45 min halves (i.e. full match duration). In this study an intermittent treadmill running protocol was used (based on the protocol of football players). However, the aim of the Taylor *et al.* (2014) study was to compare decision-making between different environmental conditions (cold: –5°C, 50% relative humidity (RH); temperate: 18°C, 50% RH; and hot: 30°C, 50% RH) and not the effects of fatigue (mental or physical) on performance *per se*. However, it might be expected that physical fatigue would be greater in the hot condition and this was supported by higher heart rate and RPE responses. Despite this, they found no differences in decision-making performance between conditions. However, the cognitive tasks and demands were likely the same between conditions in this study (meaning mental demand/fatigue was likely the same in each condition), and the authors also noted that the total physiological load may not have been sufficient to represent the physical demands of real match play (Taylor *et al.*, 2014). Watkins *et al.* (2014) studied decision-making of goal line officials in the same 3 environmental conditions (cold, temperate, and hot) and found cognitive performance was lower during cold exposure. The physiological load was even lower in this study however.

No studies have yet investigated the effects of fatigue per se on cognitive performance not the influence that additional mental fatigue may have upon this. It is crucial to investigate and provide information about mental fatigue in referees and its influence on decision-making as literature (Weston *et al.* 2012) on football referees highlighted that there is limited research on perceptual-cognitive factors and their relation with decision-making for referees. This thesis has focussed on Futsal referees in all of the previous experimental chapters, with two of the studies being field-based with analysis performed on real matches. It was concluded that laboratory-based studies which simulate the demands of match officiating were required to gain further insight and to allow more frequent measurements to be taken during, rather than being limited to before and after games only. Ideally, this would also have been conducted in Futsal referees, but it was not logistically possible to recruit Futsal referees able to come into the laboratory on the University campus (note: the previous studies were conducted with International/Elite Futsal referees from Iraq and National Futsal referees during matches in the FA National Futsal League. For this reason, county level Football referees were used in the present study to provide some relevant insight into this area but it should be acknowledged that future studies with Futsal referees are still desirable.

Hence, the aims of the current study were 1) to investigate whether mental fatigue influences referee decision-making and cognitive performance; and 2) to assess whether mental fatigue influences physiological and perceptual responses, during prolonged intermittent exercise (to simulate the physical demands of a match). It was hypothesized that mental fatigue would impair decision-making and cognitive performance, and increase perceptions of effort without affecting physiological responses to a standardised exercise bout.

II. Methods

Participants:

Twelve (12) active football referees aged between 18-45 years (mean ± SD: age 32.3 ± 10.0 years; height, 176.1 ± 5.8 cm; weight 77.9 ± 5.6 kg) volunteered to take part in the study. Participants (referees) were recruited from Kent County FA (KCFA) and the study took place in the School of Sport & Exercise Sciences (SSES) exercise physiology laboratory. Prior to participation, all referees received a written participant information sheet and were given a clear verbal explanation of the study a minimum of 24 hours prior to providing their written informed consent. Participants also completed a pre-test screening questionnaire (PAR-Q) before taking part. All methods and experimental procedures were approved by the University of Kent, School of Sport & Exercise Sciences (SSES), Research Ethics and Advisory Group (REAG) (Appendix 1).

Study design:

Each participant visited the laboratory on three separate occasions: a familiarisation (visit 1) and two main trials (control and mental fatigue, visits 2 and 3), which were conducted in a randomised (Appendix 6) and counterbalanced-crossover design. Each visit was separated by approximately 5 days. Participants were blinded to the full study aims to protect against any expectancy effects from them knowing which was the control trial. To achieve this an amended title was used on the participant information sheet and all other relevant documentation that the subjects were exposed to (e.g. consent forms etc), to read as follows: “Performance and physiological responses to exercise in referees”. After participants completed the study, referees were fully debriefed and informed of the true aims (to compare the effects of mental fatigue on performance) and that one of the cognitive function tests was intentionally more mentally taxing that the other (see specific details below). All referees confirmed verbally during the debrief (after their final visit) that they did not suspect the deception and hence the blinding procedure was successful.

Visit 1: **Familiarisation**:

The purpose of the familiarisation visit was to allow referees to practice the different tests and exercise protocols to be used in the main trials, therefore it included familiarisation with testing procedures, cognitive tests and the Stroop task, followed by running on the treadmill. Referees completed the consent and PAR-Q forms before being weighed (Seca, Hamburg, Germany) and measured for stature (Stadiometer, Holtain Ltd, Crosswell, Crymych, Dyfed, UK). They were familiarised with the cognitive function tests (Psychomotor Vigilance Test (PVT), and Stroop test) to be used during the main trials. The PVT was performed for 3 min then the Stroop test for 5 min. Participants then completed the 90 min treadmill running protocol. The intermittent protocol (see further details below) was based on the study by Drust, Reilly and Cable (2000) with modifications to the proportions of time at each speed based on recent activity analysis of football referees and assistant referees (Krustrup *et al.* 2009; Krustrup, Mohr and Bangsbo 2002 (Barbero-Alvarez *et al.* 2012)) (Table 7.1 & 7.2). Decision-making (FIFA Quiz) was assessed on the treadmill during the warm-up and in the final 13 min of the 90 min exercise protocol [when intensity was reduced to the same as during the warm-up for consistency] and PVT was assessed 4 times (before and after Stroop task, half-time and after exercise- see below and figure 7.2).

Heart rate was recorded at 15, 30, and 45 min (during the first half) and 60, 75 and 90 min (during the second-half) and using a telemetric device and chest strap (Polar Electro Oy, Kempele, Finland).

Blood lactate samples; capillary blood samples (10 μl) were collected from finger for measurement of blood lactate concentrations (C-Line, Biosen, EKF Diagnostics, Cardiff, UK). The finger was cleaned first, using a dry tissue to remove sweat, then an alcohol swab. After the area was dried, the finger was then punctured and a gentle pressure away from the site. BL was measured at three points: rest (pre-exercise), and immediately (straight within 1 min) after the end of the first half (half-time) and at post- exercise (end of the second half). ***Saliva samples*** were collected at rest and post-exercise for determination of stress-related markers (alpha-amylase and cortisol). ***The Brunel Mood Scale (BRUMS)*** was completed at 3 points: pre- Stroop task, post-Stroop task and post-exercise.

Rating of Perceived Exertion (RPE) was expressed at various times during the test; RPE the 6-20 Borg scale (Borg 1998) was recorded during exercise at 15, 30, and 45 min (during the first half) and 60, 75 and 90 min (during the second-half) (same timings as HR). Standardised instructions for the RPE scale were given to each participant, as follows:

"During running on the treadmill we want you to rate your perception of effort defined as the sensation of how hard you are driving your arm/legs in order to lift the weight/cycle. Look at the scale before you; we want you to use this scale from 6 to 20, (Figure 7.1), where 6 means "no exertion at all" and 20 means "maximal exertion". To help you choose a number that corresponds to how you feel within this range, consider the following. When you do not have the sensation of driving your arm/legs, choose number 6 ("no exertion at all") - e.g. at rest with no contraction. When you have the sensation of driving your arm/legs "hard", choose number 15. Number 20 ("Maximal exertion") corresponds to the feeling of effort when you are exercising maximally (i.e. as hard as you can for that given moment). Try to determine your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to others and you will rate by asking yourself"

rating	description
6	NO EXERTION AT ALL
7	EXTREMELY LIGHT
8	
9	VERY LIGHT
10	
11	LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD (HEAVY)
16	
17	VERY HARD
18	
19	EXTREMELY HARD
20	MAXIMAL EXERTION

Figure 7.1: Category-ratio (CR) 6-20 Borg scales. (Borg, 1998)

Table 7.1: percentage (%) of total time

	Krustrup *et al.*, (2009)		(Barbero-Alvarez *et al.* 2012)		(Krustrup, Mohr and Bangsbo 2002)		Chapter 4/study 1
Type of subject	Football Refs	Football ARs	Football Refs	Football ARs	Football ARs		Futsal referee (1st study)
Activities							
Stand %	21.9 + 4.7	45.8 + 5.4			43.9 ± 1.2		25.5 ± 3.2
Walk %	40.2 + 5.1	29.7 + 2.8	13.2	27.9	32.8 ± 1.1		34.0 ± 3.9
Jog %	15.8 + 2.9	6.3 + 1.8			8.3 ± 0.5		8.5 ± 2.0
LIR %	9.3 + 1.5	4.0 + 0.9	30	34.7	4.3 ± 0.2		5.9 ± 0.8
MIR %	4.8 + 1.5	1.9 + 0.3	30.8	24.2	2.1 ± 0.1		3.6 ± 0.5
HIR %	2.1 + 0.9	1.2 + 0.3	18.7	8.3	1.2 ± 0.1		1.3 ± 0.4
Sprint %	0.4 + 0.2	0.6 + 0.2	6.7	1.7	0.8 ± 0.1		0.6 ± 0.2
BW %	5.3 + 2.4	0.3 + 0.4			BW & SW	6.7 ± 0.9	8.7 ± 2.0
SW %	0.2 + 0.2	10.2 + 4.5					12.0 ± 3.5
Total %	100	100	100	100	100		100.0

Table 7.2: Duration:

	Krustrup *et al.*, (2009)		(Krustrup, Mohr and Bangsbo 2002)		Chapter 4/study 1
Type of subject	Football Refs	Football ARs	Football ARs		Futsal referee (1st study)
Activities (s)					
Stand	7.0 + 1.1	10.0 + 1.6	10.9 ± 0.5		20.6 ± 4.0
Walk	5.4 + 1.3	4.5 + 0.6	5.9 ± 0.3		33.6 ± 5.4
Jog	2.8 + 0.6	2.2 + 0.4	2.9 ± 0.1		8.8 ± 2.5
LIR	2.7 + 0.5	2.2 + 0.2	2.4 ± 0.1		6.7 ± 1.1
MIR	2.4 + 0.3	1.7 + 0.1	2.1 ± 0.1		4.5 ± 1.0
HIR	2.4 + 0.2	1.7 + 0.2	2.0 ± 0.1		1.6 ± 0.8
Sprint	1.9 + 0.6	1.9 + 0.2	2.1 ± 0.1		0.7 ± 0.3
BW	3.4 + 0.5	2.4 + 1.6	BW & SW	3.2 ± 0.1	9.8 ± 1.6
SW	1.5 + 0.3	3.6 + 0.8			13.9 ± 2.7
Total	4.0 + 0.1	4.9 + 0.2	5.5 ± 0.2		100.0 ± 0.0

(Mean duration (s))

Visits 2 & 3: Main trials (Experimental design):

Participants visited the laboratory to undertake the first main trial at least 5 days after the familiarisation and with at least 5 days between each test.

The actual order of the specific tests in visits 2 and 3 were randomised and assigned to each participant in a single-blind design (the researcher had to implement the tests and was aware of the study aim so it was not possible to employ a double-blind design). Subjects were required to undertake the 90 min treadmill test in one of two conditions: control or prior mental fatigue (see Figure 7.2). A PVT was conducted at 4 times during each test: baseline (before mentally fatiguing or control task), after this task but before exercise, during the half-time break and after exercise. Subjects provided a saliva sample before each cognitive test. In line with the methods of Pageaux (2014), the mentally fatiguing task was the incongruent Stroop test (response inhibition) for 30 min, whereas the control task was the congruent Stroop task (not involving response inhibition) for 30 min. Following each task, they completed the BRUMS questionnaire (Terry, Lane and Fogarty 2003) (Appendix 4) to assess their perceived mental fatigue. During exercise, they were also required to undertake the FIFA clip test (20 clips) on separate occasions as follows: during warming up 10-13 min (before 1st half) at speed 8 km^{-1} and during an equivalent intensity of steady-state activity in last 13 minutes of the 2nd half at speed 8 km^{-1}, after finishing the 90 min they completed the PVT and then the BRUMS questionnaire.

During exercise (1st and 2nd halves), referees viewed a pre-recorded international football match (that they had not previously seen) on a large screen (height 1.30 m, width 1.75 m) located in front of the treadmill. The centre of the screen was aligned with the centre of the treadmill belt (the belt was at 0.5 m above ground level) and positioned 3 m from the front of the treadmill (Figure 7.2). Participants were required to concentrate on the match and answer questions about any incidents that might occur during (e.g. whether a decision was incorrect and what the correct refereeing decision should be). The aim of this was to ensure that referees were required to maintain concentration during the run to better simulate a real match but, importantly, in an attempt to control and standardise the amount of mental effort exerted during the actual exercise between each condition (i.e. the control and prior mental fatigue trials). At specific times (beginning and end of the test) referees were required to undertake the FIFA video clips test as described above. A finger-prick blood sample was collected before and after exercise to measure lactate concentration. An unstimulated saliva sample was obtained by passive dribble (to assess cortisol and alpha-amylase) before and after the exercise (Figure 7.2).

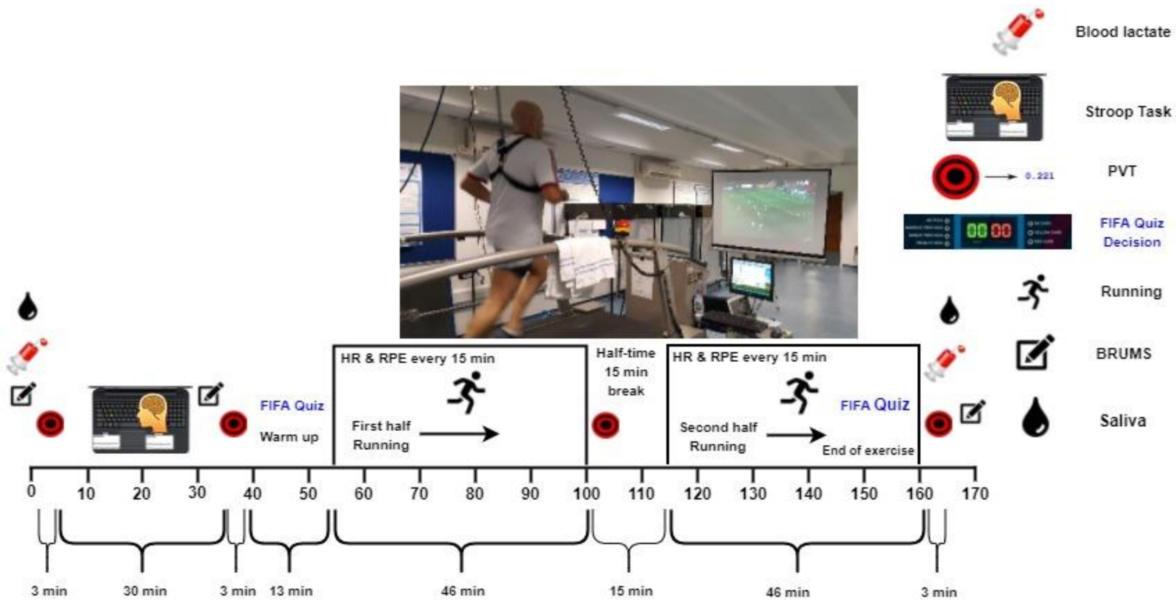


Figure 7.2: Schematic of Experimental procedure.

Decision-making assessment by FIFA DVD for referees:

The FIFA Quiz is a standard test which is used as part of the examination for referees (MacMahon *et al.* 2007; Gallardo, Iglesias and Quintana 2009; Armenteros *et al.* 2016). Here it was included in an attempt to give more practical relevance to the study and to determine the applicability of using this test in a research setting (and reliability data for this test is presented in Chapter 5). Referees completed the FIFA DVD quiz during exercise in an attempt to more closely simulate what is required during a match. However, this was during a steady state, low intensity period (during the warm-up and at the end of the 90 min trial). The DVD (which was displayed on the large screen) involved referees being presented with 20 random clips (from a possible 222) of football incidents and they were required to shout out their answer within 10 seconds of seeing the clip as detailed in the Chapter 5 (section of *FIFA Quiz*).

Psychomotor Vigilance Test (PVT): The 3 min PVT (Thorne *et al.* 2005; Basner, Mollicone and Dinges 2011) was conducted. During the task, successive visual stimuli in the form of a bullseye (Figure 7.3) are presented on the laptop screen at variable intervals and participants should respond to a visual stimuli displaying randomly from 2 to 10 sec. The inter-stimulus interval, defined as the period between the last response and the appearance of the next stimulus. Referees were instructed to observe a white screen on the screen for 3 min and press the spacebar on the keyboard each time a bullseye are appeared on the monitor.

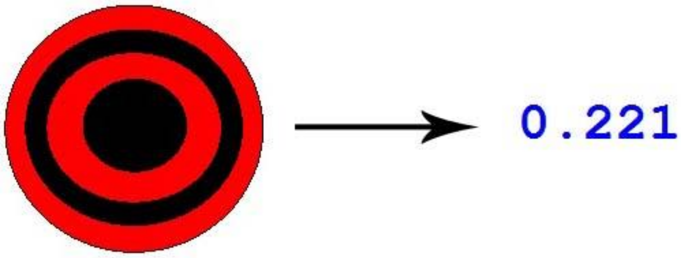


Figure 7.3: The 3 min PVT (bullseye)

Stroop Tasks

The study used two different Stroop tasks which are Congruent (serving as the control condition) and Incongruent (to induce mental fatigue) tests on a laptop computer (Figure 7.4). Subjects were familiarized with both tests during the first visit to the laboratory (without being told which was which or that there were different tests, in order to maintain blinding as mentioned above).

Congruent Task: In this condition a word appears on the screen and the colour of the font and word are the same. For example when presented with **BLUE**, the correct answer is "blue" and participants must press the key that is blue in colour on the keyboard. Participants can respond quickly because the word and the font colour match. This reduces the extent of self-regulation required by the task.). Feedback (correct or incorrect response, reaction time, and response accuracy so far) was provided on the computer screen after each word.

Incongruent Task: In this condition the word presented and the colour of the font differ and subjects must ignore the word and respond according to the font colour. For example, when presented with **BLUE**, the correct answer is "red" Reading the word interferes with identifying the font colour but participants must process this information and self-regulate (response inhibition) more in order to give the correct response. This is more demanding (cognitively) and induces mental fatigue. The modified incongruent Stroop task was used in the present study. In this version of the self-regulation task the possible words/colours are yellow, blue, green, red, which are presented on a computer screen. Subjects were instructed to press one of four coloured buttons on the computer keyboard (yellow, blue, green, red) with the correct response being the button corresponding to the ink colour (either yellow, blue, green, red) of the word. The word presented and its ink colour was randomly selected by the computer (100% incongruent). Subjects were instructed to respond as quickly and accurately as possible. Feedback (correct or incorrect response, reaction time, and response accuracy so far) was provided on the computer screen after each word.

Figure 7.4: Stroop Tasks (Congruent and Incongruent tasks)

Treadmill protocol

The protocol (Figure 7.5 & Table 7.3) required running on the treadmill (Saturn 300/125r; h/p/cosmos Sports and Medical, Nussdorf-Traunstein, Germany) for 90 min. This was intermittent in nature to give a reasonable reflection of the typical activity patterns in team sports. The protocol was based on the method of Drust, Reilly and Cable (2000) that was originally developed for football players. This protocol was modified so that the number of high-intensity efforts and the overall proportions in each activity was similar to that reported for referees (Krustrup, Mohr and Bangsbo 2002; Krustrup *et al.* 2009). Each cycle (block) lasted 12 min 42 sec, which was repeated until 45 min had elapsed for the first half (3.75 blocks). The second half was also 45 min in duration but after 32 min (2.5 blocks) of the intermittent protocol, the speed was reduced to a steady state (8 km.h^{-1}) to allow the second decision-making test to be completed with the same conditions as the first.

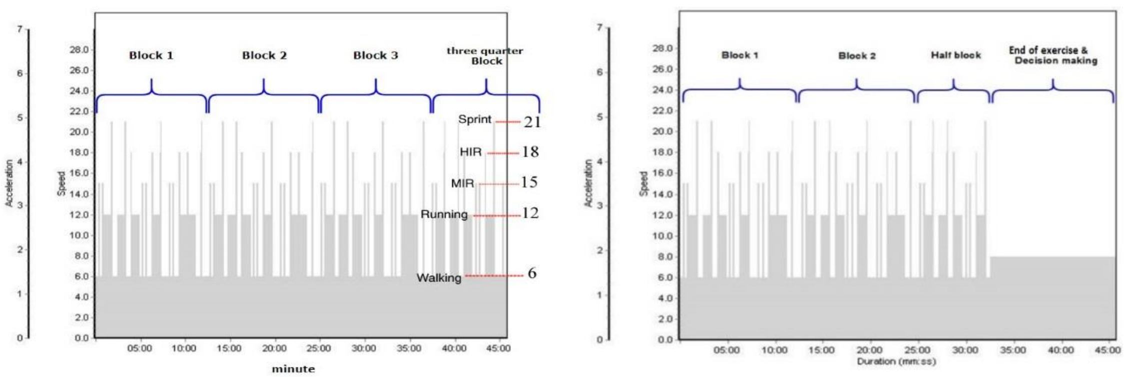


Figure 7.5: Diagrammatic representation of both halves intermittent exercise protocol

Table 7.3: Example of a block of running

No	Duration	Speed	Elevation	Acceleratio n	Distance	Total duration	Total distance
	mm:ss	km/h	%		m	mm:ss	m
1	00:20	6.0	0.0	7	0	00:20	33
2	00:06	15.0	0.0	7	0	00:26	56
3	00:19	6.0	0.0	7	0	00:45	89
4	00:06	15.0	0.0	7	0	00:51	113
5	00:50	12.0	0.0	7	0	01:41	280
6	00:03	18.0	0.0	7	0	01:44	294
7	00:03	21.0	0.0	7	0	01:47	311
8	00:35	6.0	0.0	7	0	02:22	374
9	00:50	12.0	0.0	7	0	03:12	540
10	00:03	18.0	0.0	7	0	03:15	554
11	00:03	21.0	0.0	7	0	03:18	571
12	00:35	6.0	0.0	7	0	03:53	634
13	00:05	18.0	0.0	7	0	03:58	656
14	00:50	12.0	0.0	7	0	04:48	824
15	00:20	6.0	0.0	7	0	05:08	858
16	00:06	15.0	0.0	7	0	05:14	881
17	00:19	6.0	0.0	7	0	05:33	914
18	00:06	15.0	0.0	7	0	05:39	938
19	00:35	6.0	0.0	7	0	06:14	998
20	00:05	18.0	0.0	7	0	06:19	1020
21	00:50	12.0	0.0	7	0	07:09	1187
22	00:03	18.0	0.0	7	0	07:12	1202
23	00:03	21.0	0.0	7	0	07:15	1219
24	00:55	6.0	0.0	7	0	08:10	1315
25	00:06	15.0	0.0	7	0	08:16	1338
26	00:19	6.0	0.0	7	0	08:35	1372
27	00:06	15.0	0.0	7	0	08:41	1395
28	00:35	6.0	0.0	7	0	09:16	1455
29	00:05	18	0.0	7	0	09:21	1477
30	00:50	12.0	0.0	7	0	10:11	1645
31	00:05	18.0	0.0	7	0	10:16	1669
32	00:50	12.0	0.0	7	0	11:06	1836
33	00:35	6.0	0.0	7	0	11:41	1895
34	00:03	18.0	0.0	7	0	11:44	1907
35	00:03	21.0	0.0	7	0	11:47	1925
36	00:55	6.0	0.0	7	0	12:42	2021

Saliva samples: Saliva samples were collected using standard methods (as described in Davison and Diment, 2010). For Pre-exercise samples participants were asked to rinse their mouth with plain water at least 10 min before providing the saliva sample. Participants remained seated allowed saliva to build up passively (no stimulation) in their mouth (for 2 min) before gently expectorating into the collection tube. For post-exercise samples the same procedure was followed ensuring that no fluid had been consumed for at least 10 min (i.e. in the last 10 min of exercise). Saliva volume was determined by weighing empty and filled tubes to allow estimation of saliva flow rate (taking collection duration into account). After that the sample was centrifuged for 5 min at 17,000 × g and the supernatant was stored at -80°C for later analysis of cortisol and alpha amylase by enzyme-linked immunosorbent assay (ELISA) and kinetic enzymatic photometric assay, respectively (Salimetrics, State College, Pennsylvania, USA).

Statistical analysis:

Data are presented as mean ± standard deviation (SD). Data analysis was performed using SPSS (23 Amonk, NY: IBM Corp).

A two-way repeated measures analysis of variance (ANOVA) was used to compare measures between conditions (control and mental fatigue): For decision-making there were 2 points, RPE 6 points, PVT 4 points, blood lactate 3 points, heart rate 6 points, BRUMS 3 points and salivary markers 2 points (as detailed in figure 7.2). When parametric assumptions were not met data were first normalised with Log transformation (for salivary alpha amylase and BRUMS Vigour) before analysis. Pairwise post hoc comparisons by Bonferroni corrected paired t-test were applied where required.

However, if data could not be normalised (tension, depression, anger and confusion) then non-parametric tests were used (Friedman test with post hoc Wilcoxon Matched Pairs tests when necessary).

III. Results

Decision-Making by FIFA Quiz DVD:

For correct decisions (%), there was no main effects of condition ($F_{1,11}$ = 2.88, p = 0.118), but there was a significant condition × time interaction effect ($F_{1,11}$ = 8.31, p = 0.015) and a significant effect for time ($F_{1,11}$ = 8.16, p = 0.016). Post hoc analysis showed no differences between conditions at pre-exercise (i.e. after Stroop tests) (pre-control 75.8 ± 7.9% correct, pre- mental fatigue 76.7 ± 7.2% correct, t = -0.22, p = 0.823) but scores were significantly lower post-exercise in the mental fatigue compared to control trial (post-control 74.2 ± 8.2%, post- mental fatigue 64.6 ± 7.8% correct, t = 3.72, p = 0.003). Decision-making performance post-exercise in the control trail was also maintained close to pre-exercise performance (pre- vs post-exercise, t = 0.45, p = 0.658), whereas it significantly decrease post-exercise compared to pre-exercise in the mental fatigue trial (t = 5.56, p < 0.001) (see Figure 7.6).

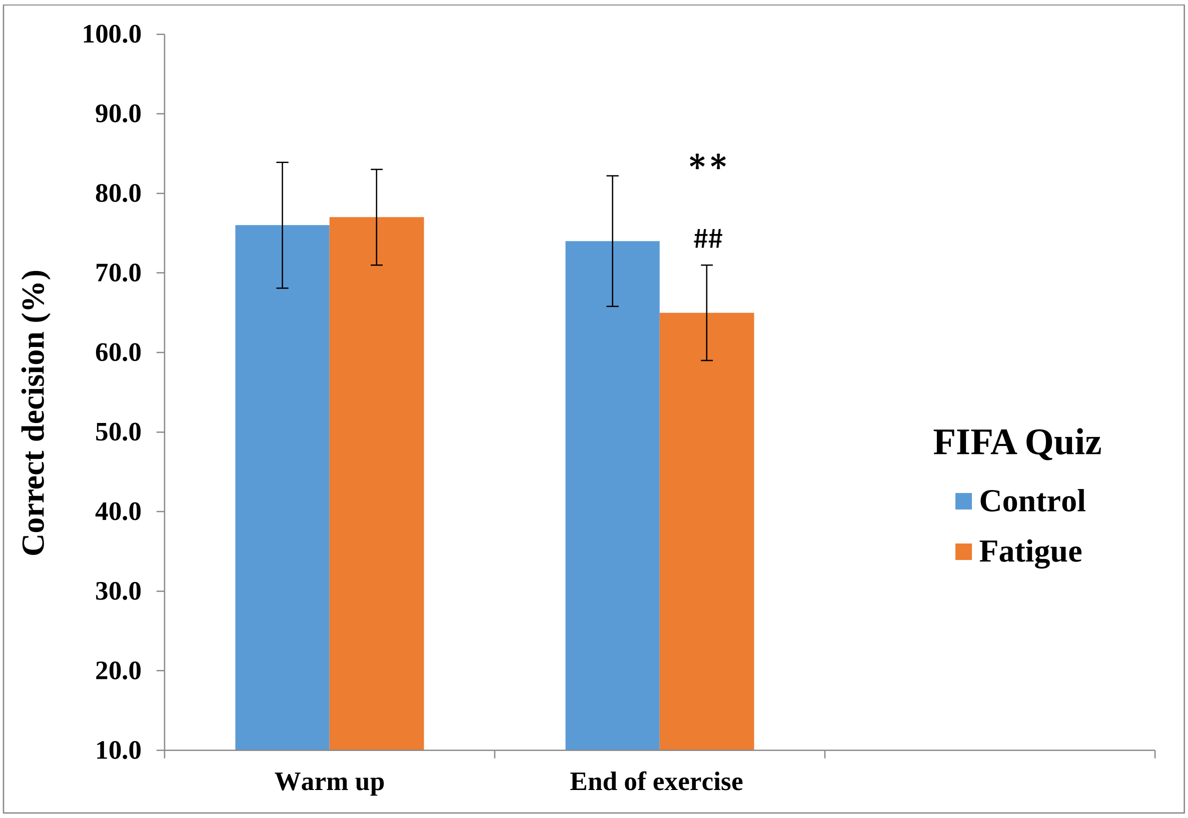


Figure 7.6: Percentage of correct Decision-making for conditions, control and fatigue

Values are mean ± SD (n=12).

Significant difference compared to pre-exercise (within trial), *p < 0.05 , **p < 0.01 .

Significant difference between trials (at same time point) $^{\#}$p < 0.05, $^{\#\#}$p < 0.01.

The Psychomotor Vigilance test (PVT):

For PVT, there were significant main effects of condition ($F_{1,11} = 8.92$, $p = 0.012$), time ($F_{3,33} = 25.23$, $p < 0.001$), and condition × time interaction ($F_{3,33} = 4.38$, $p = 0.011$). For both control and fatigue conditions, there were significant ($p < 0.05$) reductions in performance (slower RT) at all subsequent time points (post-Stroop, half-time and post-exercise) and also there was significant ($p < 0.05$) difference between post-Stroop and half-time. A significant ($p < 0.05$) difference was observed between conditions at the post-Stroop time with slower RT evident in the mental fatigue condition (see Table 7.4).

Table 7.4: Mean PVT for conditions, control and fatigue

	Pre-Stroop	Post-Stroop	Half-time	Post -exercise
control	247.6 ± 42.4	293.4 ± 59.0 **	280.2 ± 58.2 **	282.8 ± 57.7 **
Mental fatigue	244.2 ± 38.3	319.8 ± 62.6 ** - ##	288.3 ± 56.5 **	300.4 ± 70.7 **

Values are mean ± SD (n=12).

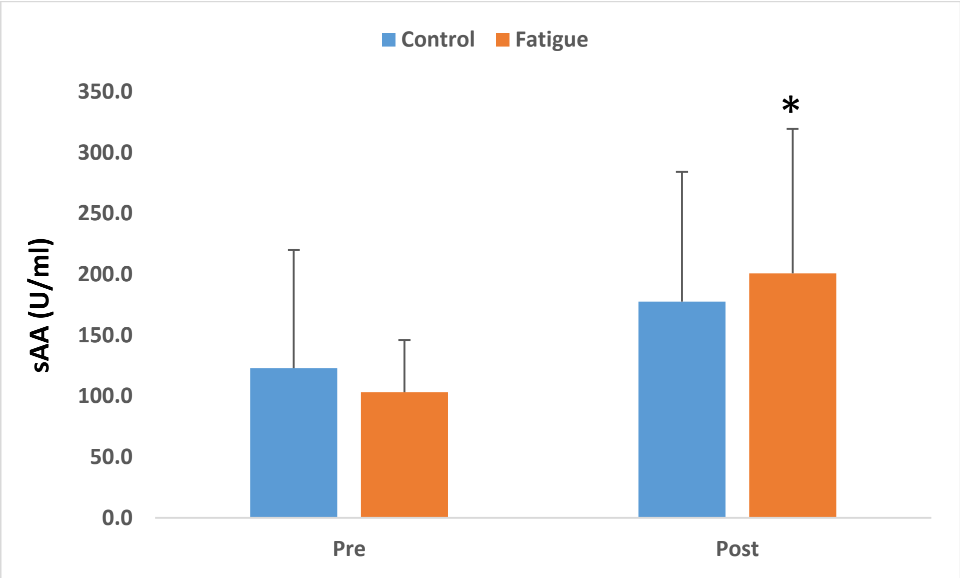
Significant difference compared to pre-exercise (within trial), *p < 0.05 , **p < 0.01 .

Significant difference between trials (at same time point) #p < 0.05, ##p < 0.01.

Salivary a-amylase and cortisol:

There were no statistically significant ($p > 0.05$) main effects of condition, time, or condition × time interaction for salivary alpha-amylase (sAA) secretion rate, salivary cortisol concentration and salivary cortisol secretion rate (sCSR) (see Table 7.5). For sAA concentration there were no significant main effects for condition ($F_{1,10} = 0.02$, $p = 0.962$) or condition × time interaction ($F_{1,10} = 0.23$, $p = 0.635$) but there was significant effect of time ($F_{1,10} = 5.32$, $p = 0.044$, see Table 7.5), with a significant increase evident post-exercise (see Figure 7.7).

Figure 7.7: sAA concentration responses to exercise



Significant difference pre- and post-fatigue condition, *$p < 0.05$

Table 7.5: Salivary cortisol and AA responses

Tests of Within-Subjects Effects (ANOVA)							
Source	**df**	**F**			**P value**		
		sAA secretion rate	sCSR	[cortisol]	**sAA** secretion rate	sCSR	[cortisol]
Condition	1, 10	0.02	0.186	0.97	0.962	0.675	0.346
Time	1, 10	5.32	0.004	2.08	0.044	0.951	0.180
Condition * Time	1, 10	0.23	1.481	0.74	0.635	0.252	0.791

Friedman Test for sAAR			
	df	Chi-Square (χ^2)	P value (Asymp. Sig).
	3	4.52	p = 0.210

Stress (sAA) for referees pre- and post-exercise

sAA (U/ml)	Control	Mental Fatigue	Statistical analysis values (t,p)
Pre	122.9 ± 97.1	103.1 ± 42.7	t = 0.48, p = 0.644
Post	177.7 ± 106.4	200.6 ± 118.6	t = -0.35, p = 0.731
Statistical analysis values (t,p)	t = -0.98, p = 0.349	t = -2.81 , p = 0.018	

Values are mean ± SD (n=11) for sAA and sAAR, (n=10) for sCS and sCSR.

Statistical analysis values for (F, p) ANOVA for parametric and Friedman Test for nonparametric. salivary a-amylase (sAA), salivary a-amylase secretion rate (sAAR), salivary cortisol secretion (sCS) and salivary cortisol secretion rate (sCSR)

Statistical analysis values (t,p) show comparisons between pre- and post-exercise.

BRUMS:

For Tension the Friedman's test revealed a significant effect ($p = 0.009$). Post hoc analysis revealed no changes across time points in the control condition ($p > 0.05$). In the mental fatigue trial there was a significant increase post-Stroop test (pre-exercise, $p = 0.011$), but not post-exercise ($p = 0.102$). Comparisons between conditions (at the same time points) revealed no difference at pre-Stroop ($p = 0.59$), a significant difference post-Stroop (higher in mental fatigue trial, $p = 0.046$), and no difference post-exercise ($p = 0.785$).

There was significant ($p < 0.05$) difference when compared between pre- and post-Stroop at fatigue condition, respectively 0.3 ± 0.6 vs 1.6 ± 1.2, z = - 2.54, p = 0.011 and also between post-Stroop and post-exercise, respectively 1.6 ± 1.2 vs 0.6 ± 0.8, z = -2.33, p = 0.020. As well as, it was significant for post-Stroop when compared between control and fatigue conditions, respectively 0.9 ± 1.2 vs 1.6 ± 1.2, z = -1.99, p = 0.046. However, there was no significant ($p > 0.05$) difference for other comparison, such as between pre- and post-Stroop for control ($p = 0.058$), post-Stroop and post-exercise for control ($p = 0.327$) or between post-exercise when compared between control and fatigue conditions (Figure 7.8 and 7.9). But for Depression, there was no significant ($p > 0.05$) difference between control and fatigue, $\chi 2 = 8.25$, $p = 0.143$.

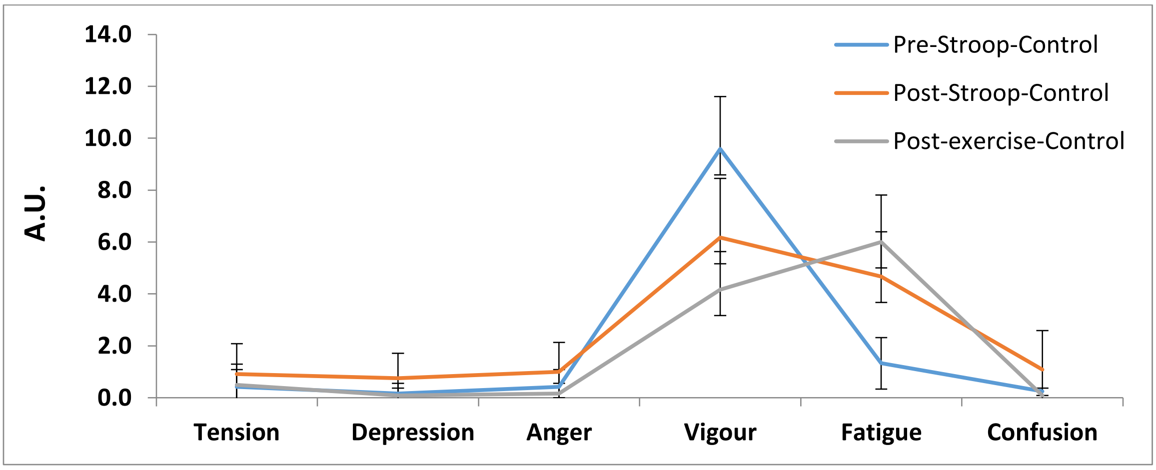


Figure 7.8: BRUMS (Arbitrary Units, A.U.), for control condition

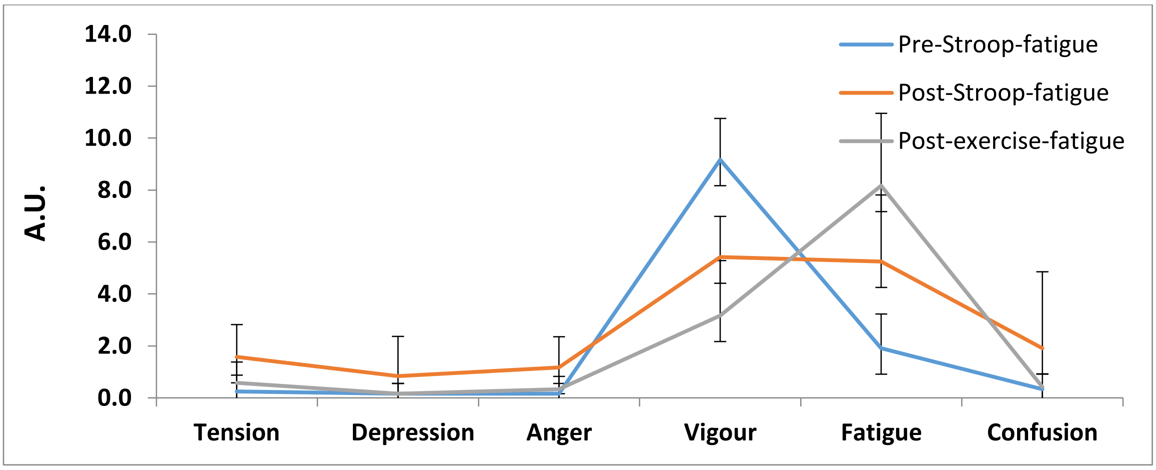


Figure 7.9: BRUMS (Arbitrary Units, A.U.), for fatigue condition

For Anger, there was significant ($p < 0.05$) difference between control and fatigue, χ^2 = 18.14, p = 0.002. There was significant ($p < 0.05$) difference when compared between post-Stroop and post-exercise at control condition, respectively 0.4 ± 0.7 vs 1.0 ± 1.1, z = - 2.45, p = 0.014, and between pre- and post-Stroop at fatigue condition 0.2 ± 0.4 vs 1.2 ± 1.2, z = - 2.80, p = 0.005, and also between post-Stroop and post-exercise for fatigue condition, respectively 1.2 ± 1.2 vs 0.3 ± 0.5, z = - 2.12, p = 0.034. However, there was no significant ($p > 0.05$) difference between pre- and for control condition, between post-Stroop of control and fatigue conditions, and between post-exercise of control and fatigue conditions (Figure 7.8 and 7.9).

For Confusion, there was significant ($p < 0.05$) difference between control and fatigue, χ^2 = 15.19, p = 0.010. There was significant ($p < 0.05$) difference when compared between post-Stroop and post-exercise at control condition, respectively 1.1 ± 1.5 vs 0.1 ± 0.3, z = - 2.04, p = 0.041, in addition there was also significant ($p < 0.05$) between pre- and post-Stroop at fatigue condition, respectively 0.3 ± 0.7 vs 1.9 vs 2.9, z = - 2.06, p = 0.039. However, there was no significant ($p > 0.05$) difference when compassion either between pre- and post-Stroop at control condition and post-Stroop and post-exercise at fatigue condition but it was almost significant, respectively z = - 1.85, p = 0.063 and – 1.93, p = 0.054. Nevertheless, there was no difference between post-Stroop at control and fatigue conditions and also between post-exercise at control and fatigue conditions (Figure 7.8 and 7.9).

For Vigour, there was significant ($p < 0.05$) difference between control and fatigue conditions, F = 6.19, p = 0.030. There was significant ($p < 0.05$) difference among times, F = 43.90, $p < 0.001$, as followings; pre-Stroop with post-Stroop, $p < 0.001$ and pre-

Stroop with post-exercise $p < 0.001$, and also post-Stroop with post-exercise $p = 0.009$. However, there was no significant ($p > 0.05$) difference between conditions and times (no interaction), $F = 2.18$, $p = 0.159$ (Figure 7.8 and 7.9).

Lastly, for fatigue, there was significant ($p < 0.05$) difference between control and fatigue conditions, $F = 6.41$, $p = 0.028$. There was significant ($p < 0.05$) difference among times, $F = 67.77$, $p < 0.001$, as followings; pre-Stroop with post-Stroop, $p < 0.001$ and pre-Stroop with post-exercise $p < 0.001$, and also post-Stroop with post-exercise $p = 0.006$. However, there was no significant ($p > 0.05$) difference between conditions and times (no interaction), $F = 2.78$, $p = 0.084$ (Figure 7.8 and 7.9).

Hear rate (HR):

There was no significant main effect of condition ($F_{1,7} = 1.91$, $p = 0.209$) or condition × time interaction ($F_{5,35} = 1.71$, $p = 0.157$). There was a significant main effect of time ($F_{5,35} = 8.63$ $p < 0.001$) (Table 7.10).

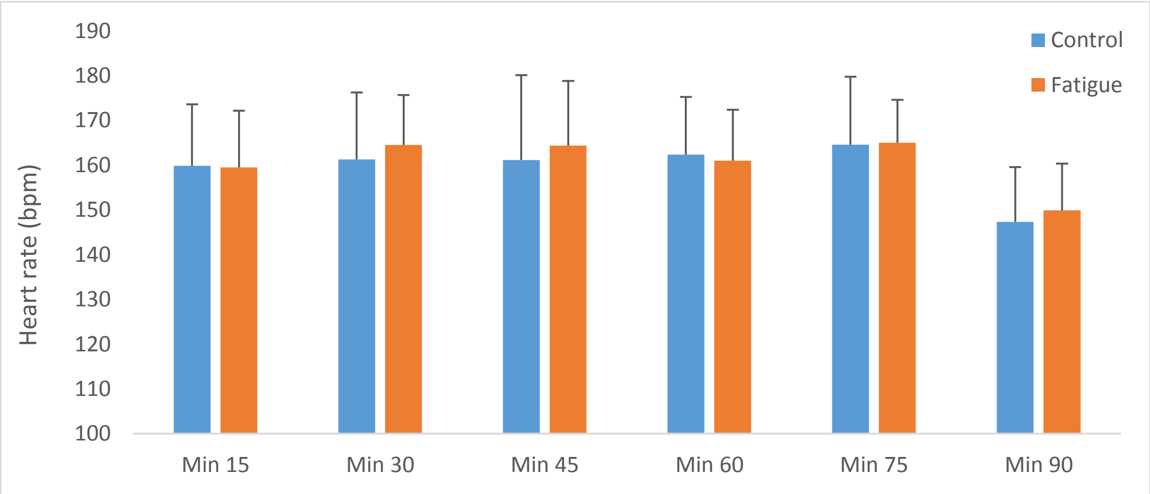


Figure 7.10: HR for conditions, control and fatigue

Blood Lactate concentration:

There was a significant main effect of condition ($F_{1,11} = 5.21$, $p = 0.043$) but no significant condition × time interaction ($F_{2,22} = 2.97$, $p = 0.072$). There was significant main effect of time ($F_{2,22} = 120.57$ $p < 0.001$), (Table 7.11).

There was a significant increase (compared to pre-exercise) at half-time and post-exercise within each condition (control and mental fatigue all $P < 0.001$). There was a significant difference between the control and mental fatigue trails at half time ($t = -2.29$, $p = 0.043$) but not post-exercise ($t = -1.38$, $p = 0.193$), (Table 7.11).

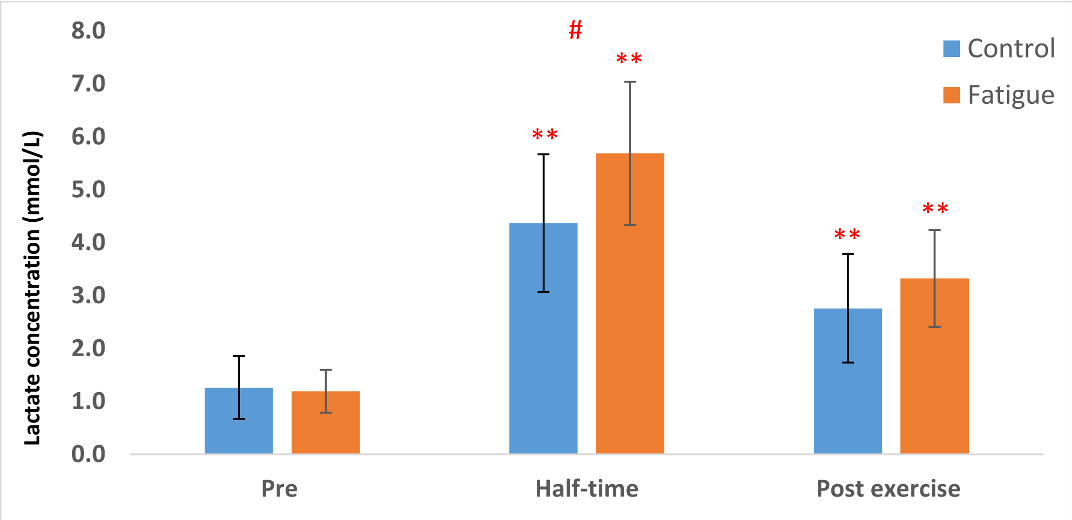


Figure 7.11: BL for conditions, control and fatigue

Significant difference compared to pre-exercise (within trial), *$p < 0.05$, **$p < 0.01$.

Significant difference between trials (at same time point) $^{\#}p < 0.05$, $^{\#\#}p < 0.01$.

Rating of Perceived Exertion (RPE) 6-20 scale:

Two way repeated measures ANOVA showed no significant main effect of condition ($F_{1,2} = F_{1,7} = 0.43$, $p = 0.529$), a significant main effect of time ($F_{5,35} = 17.82$, $p < 0.001$), and no significant condition × time interaction ($F_{5,35} = 0.87$, $p = 0.506$), (Figure 7.12).

Post hoc analysis to follow up the significant time effect identified significant differences between times for control condition, 15 min compare to 30 min, 45 min, and 75 min ($p = 0.001$, $p = 0.006$ and $p = 0.009$, respectively), and it was also observed for fatigue condition, there was significant ($p < 0.05$) differences among times 15 min compare to 30 min, 45 min, 60 min and 75 min ($p < 0.001$, 0.001, 0.006 and $p < 0.001$, respectively).

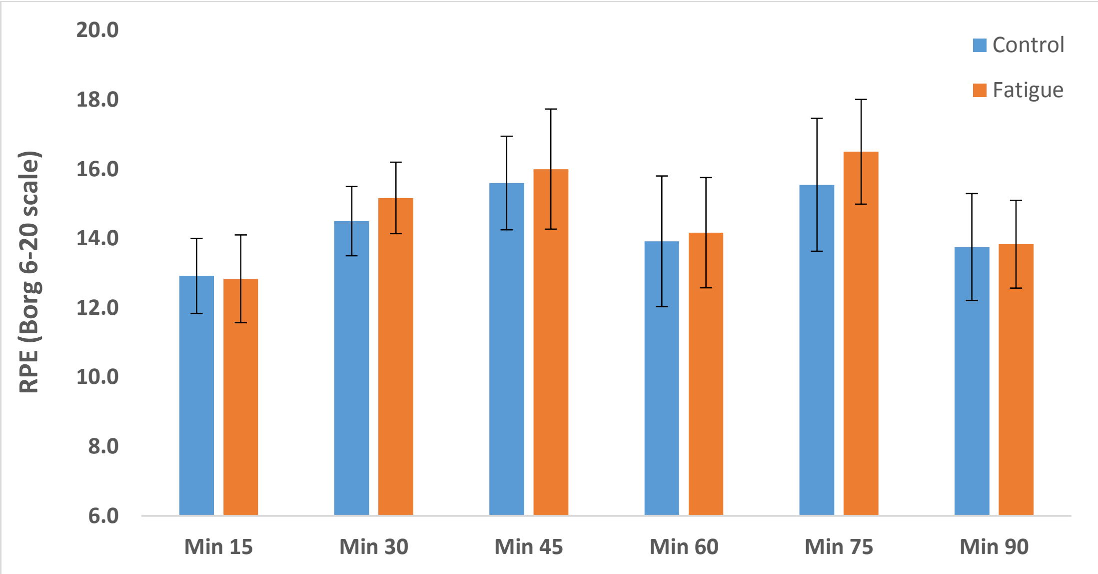


Figure 7.12: RPE 6-20 scale for conditions, control and fatigue

IV. Discussion:

The main findings were that mental fatigue resulted in worse performance on the decision-making test towards the end of exercise and reduced PVT performance. Da Silva et al. (2013) have reported that referees make more incorrect decisions in the last 15 min of a football match. However, the results did not show this in the control trial of the present study (which was intended to simulate a 'normal' match). It is a consistent finding (Catterall *et al.* 1993; Krustrup and Bangsbo 2001; Helsen and Bultynck 2004; Weston *et al.* 2007; Da Silva, Fernandes and Fernandez 2008; Mallo *et al.* 2008; Weston, Drust and Gregson 2011) that a reduction of referees' performance is observed towards the end of the match play and this might impact on decision-making. Others have reported that the distance from incidents, especially in the second half was an indication of fatigue and this could lead to incorrect decisions (Krustrup and Bangsbo 2001; Da Silva, Fernandes and Fernandez 2008). This might explain the discrepancy with the current findings, where distance from the incident was controlled (i.e. location of the screen) and not related to the referees fitness or fatigue state. Despite this, it has observed a decrease in the practical football-specific decision-making test and also a reduction in PVT in the mental fatigue condition. More recently, Badin *et al.* (2016) pointed out that mental fatigue negatively affected on players' technical performance but not on physical performance. Previous literature (Van Cutsem *et al.* 2017; Pageaux 2014) stated that prolonged performance on such a fatigue task before endurance exercise leads to higher perception of effort and impaired endurance performance.

Salivary Alpha-amylase and cortisol have been used as markers to determine stress (Nater et al. 2005), and it was reported that physical stressors (e.g. running on a treadmill) lead to increases sAA and cortisol (Gilman et al. 1979). Helsen and Bultynck (2004) pointed out that football referees were significantly stressed both physically and mentally during professional matches. In the present study, sAA was increased post-exercise, in line with the expected responses from intensive or strenuous exercise (Allgrove *et al.* 2008). However, these responses were primarily related to the physiological stress of the exercise since the pattern of response was not affected by mental fatigue, despite the fact that mental fatigue had clear effects on some of the perceptual (e.g. BRUMS) responses, or even increased one of the physiological response indicators (blood lactate, at half time). In the current study, the BRUMS scores that were significantly affected by the prior mental fatigue task, however, confirmed that mental fatigue was induced to a greater extent than in the control condition.

Blood lactate in the current study was significantly higher at half-time in the mental fatigue (compared to control) trial, which is a notable and novel finding of the present study. Many previous studies (e.g. Marcora, Staiano and Manning 2009; Pageaux 2014; Smith et al., 2016a, 2016b) have found no effect of mental fatigue on the physiological response to exercise (e.g. lactate responses) at equivalent time points between trials. This may appear to be contrary to the present findings initially, however this is likely due to differences between studies in the methods employed. For example, many previous studies have used an exercise performance trial in which participants either had to exercise until exhaustion or had to perform a self-paced exercise trial. In these studies mental fatigue reduced performance and increased perceptions of effort for the same relative intensities. In the time to exhaustion study (Marcora, Staiano and Manning 2009) there were no differences between mental fatigue and control at isotimes and blood lactate was actually lower at exhaustion in the mental fatigue condition. However, this was simply a consequence or reduced performance/a shorter time to exhaustion in the mental fatigue condition. The time trial and other self-paced exercise studies (Pageaux 2014; Smith et al., 2016a, 2016b) report no difference in lactate, but since performance was lower in the mental fatigue trials this represents a slower average pace/lower overall workload for the same lactate responses (i.e. greater lactate :exercise intensity ratio). In the current study, however, subjects did not exercise to exhaustion nor self-select the exercise intensity, but rather the intensity was controlled and was maintained the same for each trial (mental fatigue and control). As such, the additional cognitive demand and mental fatigue may have caused a greater physiological demand (as indicated by the lactate responses) whereas in a self-paced trial subjects may simply slow down/chose a slower pace in the mental fatigue condition (which would have resulted in no difference in lactate responses). This is the first study to show higher lactate response with mental fatigue and demonstrates how the addition of a mentally taxing task can add to the physiological demand induced by the exercise per se. The implications of this are the same as with the previously mentioned mental fatigue studies however, that this would likely translate to a reduction in physical performance. However, this can only be speculated from the current data since this study was not designed to assess physical performance in this way. Nevertheless, it is clear that the cognitive performance (decision-making and psychomotor vigilance) was significantly reduced in the mental fatigue condition. This has practical relevance to referee-specific performance.

Limitations

A number of other factors may influence cognitive performance, such as nutrition, hydration status (Reilly *et al.* 1985; Gopinathan, Pichan and Sharma 1988; Maughan and Leiper 1994; Da Silva and Fernandez 2003; Da Silva, Fernandes and Fernandez 2011; Dixon 2014c; Taylor *et al.* 2014; Watkins *et al.* 2014; Houssein *et al.* 2016), sleep quality and quantity acutely and chronically (Harrison and Horne 2000; Killgore, Balkin and Wesensten 2006; Barnes and Hollenbeck 2009). Because of the repeated measures nature of this study it is important to standardise such other factors and ensure consistency between repeated trials/visits. Study participants were asked to prepare as they would normally for a match and to follow the same procedures in the days before all laboratory visits, which was verbally confirmed when they attended each visit. However, it would have been useful to have them complete a prospective log of activity and nutrition in order to ensure this was followed more accurately. They also confirmed verbally that they had a normal (for them) night of sleep the night before each trial, but this was not objectively assessed or quantified. It would have been optimal if activity tracking (e.g. accelerometer devices and/or actigraph analysis) were included to more objectively and reliably quantify and confirm similar activity and sleep behaviours were indeed undertake before each trial. This was beyond the resource constraints of the present study but is recommended for future research using this model. This study was also carried out with County level referees so it is possible that different results would occur with different level referees. It will be worthwhile, therefore, if this protocol is repeated with top levels of referees. It will also be useful to apply this model to Futsal referees to determine the effects in different populations.

Conclusion

In conclusion, mental fatigue had a significant effect on referees' cognitive performance as assessed by a referee-specific decision-making task and the PVT. This may have implications for optimising referees' preparation and cognitive performance in real matches, which should be explored further.

Chapter 8

General Discussion

I. General Discussion

It is very clear that the referee plays an integral role of football and Futsal games. Referees should be sufficiently prepared/fit, mentally, physically and physiologically. One of the main priorities of refereeing during the match is cognitive performance which requires referees to keep concentration up and maintain high cognitive demands until the end of the match. It is no doubt that the main role of referees is to implement the rules of the game correctly, and so incorrect decisions could influence the outcome of the game (Surujlal and Jordaan 2013; Unkelbach and Memmert 2010).

The experimental study documented in Chapter 4 aimed to investigate the match activity profile of Futsal referees and analyse decision-making (correct and incorrect decisions) during matches. The findings of the study in Chapter 4 demonstrate that there were reductions in second half parameters (total distance covered and mean heart rate) and the proportion of incorrect decisions and missed fouls increased. In addition, previous studies pointed out that football referees total distance was reduced in the end of the match (Krustrup and Bangsbo 2001; Mallo et al. 2007; Weston et al. 2007), and this appears to be related to fatigue towards the end of the match (exercise). The majority of studies stated this reduction might be due to accumulated fatigue or changing the velocity of the game because of increased fatigue of players (Catterall *et al.* 1993; Weston *et al.* 2006; Mallo *et al.* 2008; Weston, Batterham, *et al.* 2011). Referees' cognitive performance may also be decreased in the second compared to first half of the match, which may be related to fatigue that reduces referees' concentration and can lead to misjudgements (Catteeuw, Gilis, Wagemans, *et al.* 2010b; Ager 2015).

Chapter 4 suggested a decrease in cognitive performance in the second half when assessed by proportion of correct decisions made. However, when an actual cognitive function test was applied to compare pre- and post-match performance (Chapter 6) there was no decrease (some aspects actually improved post-match). So, referees appeared able to maintain their cognitive performance over the course of the match, in opposition to the initial hypothesis that referees' PVT performance would deteriorate post-match as a result of physical and/or mental fatigue induced by the match. This might be due to the demands of the game being lower in this study compared to the 1st study (Chapter 4) as indicated by the heart rate responses, respectively 123.6 ± 20.3 bpm vs 147.7 ± 1.3 bpm (study 3 and study 1). Comparable results have been found in previous studies (Wiśnik *et al.* 2011; Chmura and Nazar 2010; Chmura *et al.* 1998) with football players in which psychomotor performance was improved after different running activities (low and high intensity). Alternatively, it could be a methodological limitation, in that the PVT could only be assessed after the match rather than during (and recovery might be very quick), whereas study 1 assessed decision-making performance actually during the match so the immediate effects of fatigue on cognitive performance may be more evident. In Chapter 7, when exercise intensity was controlled in a laboratory-based simulation study, decision-making performance did not decrease in the control trial (assessed during the end of exercise), although PVT performance was decreased during and after exercise (and the addition of mental fatigue worsened these decrements).

Physiological demands (heart rate and blood lactate) were investigated in all studies in this thesis. The field study in the Chapter 4 pointed out that mean heart rate for the whole Futsal match was 147.7 ± 1.3 bpm which was similar to previous studies (Rebelo *et al.* 2011; Dixon 2014a) on Futsal referees. Additionally, there was a reduction from the first half compared to the second half 150.9 ± 1.9 vs 144.5 ± 2.6, respectively, which was similar to that reported in other studies (Rebelo *et al.* 2011; Dixon 2014a) that have been done on Futsal referees. However, the heart rate in the field study in Chapter 6 was lower 125.6 ± 20.5 vs 121.7 ± 20.8 bpm (1^{st} vs. 2^{nd} halves) than reported in the Chapter 4 on Futsal referees. This could be a good indicator as to why the PVT post-match was higher than pre-match (in Chapter 6), as this heart rate could indicate the demand of the game was low. It is also possible that the different populations (Chapter 4 ‘‘Iraqi Futsal referees’’ and Chapter 6 ‘‘FA Futsal referees’’) studied offer some explanation for the differences. The last experimental study (Chapter 7) was on football referees and mean heart rate was higher compared to other studies in this thesis (control 159.3 ± 15.2 and mental fatigue trials 160.4 ± 12.4 respectively). This study differed to the field studies because it was a lab-based simulation in which intensity was externally controlled, which explains the observation of no difference between the first and the second halves. Previous studies (Krustrup and Bangsbo 2001; Reilly and Gregson 2006; Costa *et al.* 2013) indicated that mean heart rate of football referees ranged between 160-166 bpm during a match.

Blood lactate is another physiological indicator collected in this thesis. In the field study in Chapter 4 blood lactate was taken during actual Futsal matches at three points, pre-match, half-time and post-match, respectively 1.27 ± 0.32 mM, 1.98 ± 0.53 mM and 2.12 ± 0.41 mM. However, previous studies (Rebelo *et al.* 2011; Dixon 2014b) on Futsal referees indicated that post-match blood lactate was lower when compared to half-time, and our blood lactate at post-match was in line with other studies (Krustrup and Bangsbo 2001; Krustrup, Mohr and Bangsbo 2002; Krustrup *et al.* 2009) on football referees. In the study in Chapter 7 blood lactate samples collected at three points as pre-, half-time and post-exercise for football referees and it found that blood lactate was increased at half-time and post-exercise which was the same as the 1st study when Futsal referees' blood lactate was increased at half-time and post-match. However, in Chapter 7 the blood lactate responses were influenced by mental fatigue, which has not been reported previously.

The study in Chapter 7 explored cognitive performance in football referees in regards to both psychomotor performance (PVT) and decision-making (FIFA test DVD). In addition, the effects of mental fatigue on cognitive performance were also investigated (decision-making and cognitive function at various points before, during and after exercise). In Chapter 4 there was evidence of decreased performance (greater proportion of errors) in the second half in Futsal referees in a field based study with analysis on actual match performance, similar to findings in football referees in previous studies (Krustrup and Bangsbo 2001; Mallo *et al.* 2008; Mallo *et al.* 2010; Elsworthy and Dascombe 2011; Barbero-Alvarez *et al.* 2012; Elsworthy, Burke and Dascombe 2014). Therefore, in Chapter 7 a laboratory-based simulation was used to allow more control over the exercise intensity and duration (which were standardised) and to allow the implementation of a mental fatigue intervention to determine whether this influences performance (in Football referees). Results from Chapter 7 demonstrate that mental fatigue did impair cognitive performance and decision-making. Moreover, the mental fatigue task influenced mood states (BRUMS) between pre- and post-exercise. Overall, the mental fatigue task influenced referee' performance. Therefore, it can be concluded that prior mental fatigue impairs referees' cognitive performance and thus it should be taken in consideration that referees' should be mentally prepared before the match, especially those referees who have other jobs and commitments (or may be exposed to cognitively demanding tasks) before their match in order to avoid any mental factor that might be affect their performance.

Mood states (BRUMS) were examined in Chapters 5, 6 and 7 in this thesis. The experimental study in Chapter 5 investigated mood states pre- and post- decision-making test for football referees in two conditions (control and PVT) as a pilot study to ensure the PVT did not affect decision-making performance. The BRUMS findings of study 3 (Chapter 6) and study 4 (Chapter 7) were high as there was physical and mental demands, especially in Chapter 7 where referees intensity was externally dictated concurrent with the performance of a mental task/sustained concentration. In Chapter 6 referees recorded high scores of fatigue (when the mean heart rate was 123.6 ± 20.3 bpm), so the results for post-match fatigue and vigour could be due to the referees self-reporting that they feel less energy and are tired being affected by expectancy effects, although this remains speculation at present. Using the session RPE (Borg's CR10-scale, as modified by Foster et al., 2001) was another variable collected in the 1st and 3rd studies (Chapter 4 and 6). The results concluded that there was significant difference at half time compared to post-match. It was observed that the session RPE in Chapter 4 and 6 is different because in the Chapter 4 when the RPE rate was 6.8 vs 7.1 (half-time and post-match) heart rate reached 150.9 ± 1.9 vs 144.5 ± 2.6 bpm but in Chapter 6 the heart rate was lower 125.6 ± 20.5 vs 121.7 ± 20.8 bpm, therefore the tempo/intensity of the game was higher in the Chapter 4 and secondly it might be affected by the fact that the study population was different (Iraqi Futsal referees vs. the FA Futsal referees).

It was indicated in the literature review (Mallo et al. 2012; Mascarenhas et al. 2009) that football referees made 21 to 25 decisions per match, however no previous study has examined the number of decisions made by Futsal referees per match. In Chapter 4 Futsal referees made an average of 17 (range 10 to 21) decisions during a match which was similar to football. Due to the smaller pitch in Futsal and fast nature of the game it might be expected that more incidents and hence decisions would occur in Futsal. However, this was not the case based on the present study (Chapter 4). Nevertheless, the overall cognitive demand is likely to be different in Futsal due to the Futsal rules (FIFA 2014, p.94) and requirement for a quicker decision time, typically within 2 s (Galan 2016) in Futsal referees. In addition, since Futsal referees also need to attend to both the action area (where players are challenging for the ball) and influence area (off the ball movements). For example, one third of fouls and misconduct in Futsal occurred in the influence area in the recent FIFA Futsal World Cup 2016 (Galan 2016). Taking all of this into account, it would seem that cognitive demands are greater in Futsal, and for this reason it was anticipated a greater negative impact on markers of cognitive function after the Futsal matches. Although decision-making performance was decreased in the 2nd half compared to the first half in study 1 of this thesis (Chapter 4) no reduction of cognitive function (as assessed by PVT) was observed after real Futsal matches (Chapter 6), although in this study the overall physical demand (intensity) was lower than previously reported in the literature and in Chapter 4 of this thesis. On the one hand, however, although Futsal may have a greater cognitive demand (as discussed above) Football may have greater physical demand, due to greater total distance covered by referees in a match. For this reason, to fully understand the practical relevance of these subtle differences between Futsal and football refereeing future research is required which compares decision making during the various stages/times of real matches (in both Futsal and football), compares cognitive function (e.g. PVT) before and after Futsal and football matches, and also utilises lab-based simulation protocols (as used in Chapter 7) but with Futsal referees (and the exercise protocol to be based on analysis of Futsal match physiological demands and profile).

Statistical approach and the concept of practical relevance vs statistical significance. Despite the significant differences observed throughout this thesis, the practical relevance of these findings is not known. It is becoming increasingly popular to integrate practical relevance into sport and exercise sciences research studies and in some areas statistical analyses like magnitude-based inferences (Batterham and William 2006) are used preferentially over traditional inferential statistics. The idea is that this better represents the practical relevance of the findings and applicability/relevance to the ‘real world’. However, this requires some judgement from the researchers on what constitutes a “worthwhile effect magnitude” (Wilkinson 2014). Since there is very little evidence or research currently available on Futsal referee performance (physical or cognitive) it was not possible to make a practical and objective judgement about what would constitute a worthwhile change or difference in this context, so the study has used the traditional inferential statistical approach only. It should be acknowledged this is a limitation that could be addressed in future research as more data, and practically focused studies, become available in this area.

In conclusion, the role of factors that affect referees’ cognitive performance are important to consider. Referees’ cognitive performance was seen to decrease in the end of the match (exercise) in terms of incorrect decision-making either in filed and laboratory studies. In the laboratory study prior mental fatigue increased the amount of detriment on cognitive performance, showing that this can increase the negative effects of physical fatigue on this aspect of referee performance. In the late stages of a match, particularly when the demands of the game are high (both physical and mental) it might be expected that referees performance will be affected. However, in Chapter 6 cognitive performance was shown to be increased post-match, which might have been a result of the lower intensity. This presents the potential for strategies to enhance cognitive performance to be developed (e.g. warm-up strategies) but it must be acknowledged that this finding could also be a consequence of the fact that the PVT could only be performed after and not during the game, but this warrants further investigation.

It is important to pay attention to referees' cognitive performance as it is the priority of referees to keep up with play and control the game and make correct decisions. More research is required to understand referees' cognitive performance and implement strategies that could be used to improve performance or to develop training programmes to improve performance.

II. Practical Applications

- **1st study;** Futsal referees suffer fatigue in the second half, which may have practical implications for their ability to perform optimally (e.g. keep up with play in order to make decisions). They made a greater proportion of incorrect decisions in the second half. Coaches can use this information to optimise training with the aim of improving sports-specific fitness to maintain performance throughout the whole match and try to reduce declines in decision-making performance.
- The new FIFA testing battery for Futsal referees seems better suited to determine sport-specific fitness due to better relationships with match activity profile. However, this battery still lacks any assessment of backwards movements, which could be incorporated in the future to increase specificity further.
- **2nd study;** Due to the fact that the 10 min PVT does not influence referees' cognitive performance (when performed 60 min prior), it can be used with referees before real competition/in the field to assess psychomotor performance/cognitive function.
- **3rd study;** The improved PVT performance, post-exercise, when exercise intensity was lower could be used to inform pre-match preparation (e.g. warm-up) with a view to optimising cognitive preparation/performance although further work is required to identify the optimal (and/or minimal) durations and intensities of exercise required to elicit this

- **4th study;** mental fatigue has a negative effect on cognitive performance so referees should try to minimise this as much as possible before matches and/or implement strategies to reduce the effects of mental fatigue.

III. Recommendations and future study:

- **1st study** suggested that intermittent fitness tests are more suitable and sport-specific in relation to Futsal referees' performance but also that some activity types are not covered (e.g. backwards running) in the tests. This could be implemented into future studies and test development.
- **3rd study:** As the PVT performance improved post-match it would be useful to assess PVT during exercise (match simulation lab study) and also to test the efficacy of various warm-up strategies before matches to see whether they improve performance in subsequent matches.
- **4th study**: Mental fatigue had a significant effect on referees' cognitive performance. This model could be applied with Futsal referees or any other sport referees also. Furthermore, this model could be used to test the effects of other strategies and whether they can negate the effects of mental fatigue on refereeing performance (e.g. effects of different warm-ups as suggested above; effects of training interventions such as video training programmes; effects of nutritional strategies such as caffeine, carbohydrate; hydration etc). Other factors can also be assessed with this protocol, such as the effects of sleep and sleep behaviours.

References

Ben Abdelkrim, N., El Fazaa, S. and El Ati, J. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British journal of sports medicine* [Online] **41**:69–75. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2658931&tool=pmcentrez&rendertype=abstract.

Adnan, R., Muzayin, N. and Sulaiman, N. (2013). Analysis of movement pattern among referee in 2012 Malaysian Cup. *Journal of Human Sport and Exercise* **8**.

Ager, D. (2015). *The Soccer Referee's Manual*. London and New York: Bloomsbury Publishing.

Allgrove, J.E. *et al.* (2008). Effects of exercise intensity on salivary antimicrobial proteins and markers of stress in active men. *Journal of Sports Sciences* **26**:653–661.

Armenteros, M. *et al.* (2016). The Video Database for Teaching and Learning in Football Refereeing. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering* **10**:3103–3108.

Atkinson, G. and Nevill, A. (1998). Statistical Methods for Assssing Measurement Error (Reliability) in Variables Relevant to Sports Medicine. *Sports Medicine* [Online] **26**:217–238. Available at: http://link.springer.com/article/10.2165/00007256-199826040-00002.

Badin, O.O. *et al.* (2016). Mental Fatigue Impairs Technical Performance in Small-Sided Soccer Games. *International journal of sports physiology and performance,* **11**:1100–1105.

Ballester, R. *et al.* (2015). The relationship between regular sports participation and vigilance in male and female adolescents. *PLoS ONE* **10**:1–12.

Bangsbo, J., Iaia, F.M. and Krustrup, P. (2008). The Yo-Yo Intermittent Recovery Test. *Sports Medicine* [Online] **38**:37–51. Available at: http://dx.doi.org/10.2165/00007256-200838010-00004.

Bangsbo, J., Nørregaard, L. and Thorsoe, F. (1991). Activity profile of competition soccer. *Canadian journal of sport sciences= Journal canadien des sciences du sport* **16**:110–116.

Barbero-Alvarez, J.C. *et al.* (2008). Match analysis and heart rate of futsal players during competition. *Journal of sports sciences* **26**:63–73.

Barbero-Alvarez, J.C. *et al.* (2012). Physical and Physiological Demands of Field and Assistant Soccer Referees During America's Cup. *Journal of Strength and Conditioning Research* **26**:1383–1388.

Barnes, C.M. and Hollenbeck, J.R. (2009). Sleep deprivation and decision-making teams: Burning the midnight oil or playing with fire? *Academy of Management Review* **34**:56–66.

Basner, M., Mollicone, D. and Dinges, D.F. (2011). Validity and sensitivity of a brief psychomotor vigilance test (PVT-B) to total and partial sleep deprivation. *Acta Astronautica* [Online] **69**:949–959. Available at: http://dx.doi.org/10.1016/j.actaastro.2011.07.015.

Batterham, A.M. and William, G.H. (2006). Making meaningful inferences about magnitudes. *International journal of sports physiology and performance* **1**:50–57.

Blais, A.R., Thompson, M.M. and Baranski, J. V. (2005). Individual differences in decision processing and confidence judgments in comparative judgment tasks: The role of cognitive styles. *Personality and Individual Differences* **38**:1701–1713.

Bland, M.J. and Altman, D. (1986). Statistical Methods for Assessing Agreement Between Two Methods of Clinical Measurement. *The Lancet* **327**:307–310.

Boksem, M.A.S. and Tops, M. (2008). Mental fatigue: Costs and benefits. *Brain Research Reviews* [Online] **59**:125–139. Available at: http://dx.doi.org/10.1016/j.brainresrev.2008.07.001.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales.* Human kinetics.

Borin, J.P. *et al.* (2013). The distances covered by basketball referees in a match increase throughout the competition phases, with no change in physiological demand. *Open access journal of sports medicine* [Online] **4**:193–198. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3871407&tool=pmcentrez&rendertype=abstract.

Brand, R., Plessner, H. and Schweizer, G. (2009). Conceptual considerations about the development of a decision-making training method for expert soccer referees. *Perspectives on Congition and Action in Sport*:181–190.

Brisswalter, J., Callardeau, M. and René, A. (2002). Effects of acute physical exercise on cognitive performance. *Sports medicine (Auckland, N.Z.)* **32**:555–566.

Burns, T.I.M. (2003). Holistic Futsal a Total Mind-Body-Spirit Approach.

Casajus, J.A. and Castagna, C. (2007). Aerobic fitness and field test performance in elite Spanish soccer referees of different ages. *Journal of Science and Medicine in Sport* **10**:382–389.

Castagna, C. *et al.* (2009). Match demands of professional Futsal: A case study. *Journal of Science and Medicine in Sport* **12**:490–494.

Castagna, C., Abt, G. and D’ottavio, S. (2004). Activity profile of international-level soccer referees during competitive matches. *The Journal of Strength & Conditioning Research* **18**:486–490.

Castagna, C., Abt, G. and D’ottavio, S. (2007). Physiological aspects of soccer refereeing performance and training. *Sports medicine* **37**:625–646.

Castagna, C., Abt, G. and D’ottavio, S. (2002). Relation Between Fitness Tests and Match Performance in Elite Italian Soccer Referees. *Journal of Strength and Conditioning Research* [Online] **16**:231–235. Available at: http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00124278-200205000-00010.

Castagna, C., Abt, G. and D’Ottavio, S. (2005). Competitive-level differences in Yo-Yo intermittent recovery and twelve minute run test performance in soccer referees. *Journal of strength and conditioning research / National Strength & Conditioning Association* **19**:805–809.

Castagna, C. and D’ottavio, S. (2001). Effect of maximal aerobic power on match performance in elite soccer referees. *Journal of strength and conditioning research / National Strength & Conditioning Association* **15**:420–425.

Castillo, D. *et al.* (2016). Physical fitness and physiological characteristics of soccer referees. *Science and Sports* [Online] **31**:27–35. Available at: http://dx.doi.org/10.1016/j.scispo.2015.11.003.

Catteeuw, P., Helsen, W., Gilis, B. and Wagemans, J. (2009). Decision-making skills, role specificity, and deliberate practice in association football refereeing. *Journal of Sports Sciences* [Online] **27**:1125–1136. Available at:

http://www.tandfonline.com/doi/abs/10.1080/02640410903079179.

Catteeuw, P., Gilis, B., García-Aranda, J.-M., *et al.* (2010). Offside decision making in the 2002 and 2006 FIFA World Cups. *Journal of Sports Sciences* [Online] **28**:1027–1032. Available at: http://www.tandfonline.com/doi/abs/10.1080/02640414.2010.491084.

Catteeuw, P., Gilis, B., Wagemans, J., *et al.* (2010a). Offside decision making of assistant referees in the English Premier League: Impact of physical and perceptual-cognitive factors on match performance. *Journal of Sports Sciences* [Online] **28**:471–481. Available at: http://www.tandfonline.com/doi/abs/10.1080/02640410903518184.

Catteeuw, P., Gilis, B., Wagemans, J., *et al.* (2010b). Perceptual-cognitive skills in offside decision making: Expertise and training effects. *Journal of Sport and Exercise Psychology* [Online] **32**:828–844. Available at: http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=57956852&site=ehost-live%5Cnhttp://www.tandfonline.com/doi/abs/10.1080/02640414.2010.491084%5Cnhttp://journals.humankinetics.com/doi/10.1123/jsep.32.6.845.

Catteeuw, P., Helsen, W., Gilis, B., Van Roie, E., *et al.* (2009). Visual scan patterns and decision-making skills of expert assistant referees in offside situations. *Journal of sport & exercise psychology* **31**:786–797.

Catterall, C. *et al.* (1993). Analysis of the work rates and heart rates of association football referees. *British journal of sports medicine* [Online] **27**:193–196. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1332186&tool=pmcentrez&rendertype=abstract.

Causer, J. and Ford, P.R. (2014). ‘Decisions, decisions, decisions’: Transfer and specificity of decision-making skill between sports. *Cognitive Processing* **15**:385–389.

Chang, Y.K. *et al.* (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research* [Online] **1453**:87–101. Available at: http://dx.doi.org/10.1016/j.brainres.2012.02.068.

Chmura, J. *et al.* (1998). Psychomotor performance during prolonged exercise above and below the blood lactate threshold. *European Journal of Applied Physiology and Occupational Physiology* **77**:77–80.

Chmura, J. and Nazar, K. (2010). Parallel changes in the onset of blood lactate accumulation (OBLA) and threshold of psychomotor performance deterioration during incremental exercise after training in athletes. *International Journal of Psychophysiology* [Online] **75**:287–290. Available at: http://dx.doi.org/10.1016/j.ijpsycho.2009.12.011.

Cooper, S.R. *et al.* (2017). The role of psychometrics in individual differences research in cognition: A case study of the AX-CPT. *Frontiers in Psychology* **8**:1–16.

Costa, E.C. *et al.* (2013). Monitoring external and internal loads of Brazilian soccer referees during official matches. *Journal of Sports Science and Medicine* **12**:559–564.

Van Cutsem, J. *et al.* (2017). The effects of Mental Fatigue on Physical Performance: A Systematic Review. *Sports Medicine* **47**:1569–1588.

D'ottavio, S. and Castagna, C. (2001a). Analysis of match activities in elite soccer referees during actual match play. *The Journal of Strength & Conditioning Research* **15**:167–171.

D'ottavio, S. and Castagna, C. (2001b). Physiological load imposed on elite soccer referees during actual match play. *Journal of Sports Medicine and Physical Fitness* **41**:27–32.

Dinges, D.F. *et al.* (1987). Temporal placement of a nap for alertness: Contributions of circadian phase and prior wakefulness. *Sleep* **10**:313–329.

Dinges, D.F. and Powell, J.W. (1985). Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. *Behavior Research Methods, Instruments, & Computers* **17**:652–655.

Dinges, J.D.F. *et al.* (1997). Cumulative Sleepiness, Mood Disturbance, and Psychomotor Vigilance Performance Decrements During a Week of Sleep Restricted to 4–5 Hours per Night. *Sleep* [Online] **20**:267–277. Available at: https://academic.oup.com/sleep/article/20/4/267/2732104/Cumulative-Sleepiness-Mood-Disturbance-and.

Dixon, D. (2014a). A Pilot Study of the Physiological Demands of Futsal Referees Engaged in International Friendly Matches. *American Journal of Sport Science and Medicine* **2**:103–107.

Dixon, D. (2014b). A Retrospective Study of the Yo-Yo IE2 Test: Can It be Used to Differentiate Between Different Levels of Futsal Referees? *American Journal of Sports Science and Medicine* [Online] **2**:93–97. Available at: http://pubs.sciepub.com/ajssm/2/3/5/index.html.

Dixon, D. (2014c). An examination of the relationship between decision making and hydration status in Futsal Referees. In: *Book of Abstracts*. pp. 22–23.

Dogramaci, S.N., Watsford, M.L. and Murphu, A.J. (2011). Time-motion analysis of international and national level futsal. *The Journal of Strength & Conditioning Research* **25**:646–651.

Doğramacı, S.N. and Watsford, M.L. (2006). A comparison of two different methods for time-motion analysis in team sports. *International Journal of Performance Analysis in Sport* **6**:73–83.

Dohmen, T.J. (2008). The influence of social forces: Evidence from the behavior of football referees. *Economic Inquiry* **46**:411–424.

Doran, S.M., Van Dongen, H.P.A. and Dinges, D.F. (2001). Sustained attention performance during sleep deprivation: evidence of state instability. *Archives Italiennes de Biologie* **139**:253–267.

Dorrian, J., Rogers, N.L. and Dinges, D.F. (2005). Psychomotor vigilance performance: Neurocognitive assay sensitive to sleep loss. In: *Sleep Deprivation: Clinical Issues, Pharmacology and Sleep Loss Effects*. pp. 39–70.

Drust, B., Reilly, T. and Cable, N.T. (2000). Physiological responses to laboratory-based soccer-specific intermittent and continuous exercise. *Journal of sports sciences* [Online] **18**:885–892. Available at: http://www.tandfonline.com/doi/abs/10.1080/026404100750017814.

Ekblom, B. (1986). Applied Physiology of Soccer. *Sports Medicine* **3**:50–60.

Ellemberg, D. and St-Louis-Deschênes, M. (2010). The effect of acute physical exercise on cognitive function during development. *Psychology of Sport and Exercise* **11**:122–126.

Elsworthy, N., Burke, D. and Dascombe, B.J. (2014). Factors relating to the decision-making performance of Australian football officials. *International Journal of Performance Analysis in Sport* [Online] **14**:401–410. Available at: http://www.evolutionarycognition.org/papers/Elsworthy et al. (2014) Edited Proof.pdf.

Elsworthy, N., Burke, D. and Dascombe, B.J. (2016). Physical and psychomotor performance of Australian football and rugby league officials during a match simulation. *Journal of sports sciences* [Online] **34**:420–428. Available at: http://dx.doi.org/10.1080/02640414.2015.1057208.

Elsworthy, N. and Dascombe, B.J. (2011). The match demands of Australian rules football umpires in a state-based competition. *International Journal of Sports Physiology and Performance* **6**:559–571.

Ben Abdelkrim, N., El Fazaa, S. and El Ati, J. (2007). Time-motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British journal of sports medicine* [Online] **41**:69–75. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2658931&tool=pmcentrez&rendertype=abstract.

Adnan, R., Muzayin, N. and Sulaiman, N. (2013). Analysis of movement pattern among referee in 2012 Malaysian Cup. *Journal of Human Sport and Exercise* **8**.

Ager, D. (2015). *The Soccer Referee's Manual*. London and New York: Bloomsbury Publishing.

Allgrove, J.E. *et al.* (2008). Effects of exercise intensity on salivary antimicrobial proteins and markers of stress in active men. *Journal of Sports Sciences* **26**:653–661.

Armenteros, M. *et al.* (2016). The Video Database for Teaching and Learning in Football Refereeing. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering* **10**:3103–3108.

Atkinson, G. and Nevill, A. (1998). Statistical Methods for Assssing Measurement Error (Reliability) in Variables Relevant to Sports Medicine. *Sports Medicine* [Online] **26**:217–238. Available at: http://link.springer.com/article/10.2165/00007256-199826040-00002.

Badin, O.O. *et al.* (2016). Mental Fatigue Impairs Technical Performance in Small-Sided Soccer Games. *International journal of sports physiology and performance,* **11**:1100–1105.

Ballester, R. *et al.* (2015). The relationship between regular sports participation and vigilance in male and female adolescents. *PLoS ONE* **10**:1–12.

Bangsbo, J., Iaia, F.M. and Krustrup, P. (2008). The Yo-Yo Intermittent Recovery Test. *Sports Medicine* [Online] **38**:37–51. Available at: http://dx.doi.org/10.2165/00007256-200838010-00004.

Bangsbo, J., Nørregaard, L. and Thorsoe, F. (1991). Activity profile of competition soccer. *Canadian journal of sport sciences= Journal canadien des sciences du sport* **16**:110–116.

Barbero-Alvarez, J.C. *et al.* (2008). Match analysis and heart rate of futsal players during competition. *Journal of sports sciences* **26**:63–73.

Barbero-Alvarez, J.C. *et al.* (2012). Physical and Physiological Demands of Field and Assistant Soccer Referees During America’s Cup. *Journal of Strength and Conditioning Research* **26**:1383–1388.

Barnes, C.M. and Hollenbeck, J.R. (2009). Sleep deprivation and decision-making teams: Burning the midnight oil or playing with fire? *Academy of Management Review* **34**:56–66.

Basner, M., Mollicone, D. and Dinges, D.F. (2011). Validity and sensitivity of a brief psychomotor vigilance test (PVT-B) to total and partial sleep deprivation. *Acta Astronautica* [Online] **69**:949–959. Available at: http://dx.doi.org/10.1016/j.actaastro.2011.07.015.

Batterham, A.M. and William, G.H. (2006). Making meaningful inferences about magnitudes. *International journal of sports physiology and performance* **1**:50–57.

Blais, A.R., Thompson, M.M. and Baranski, J. V. (2005). Individual differences in decision processing and confidence judgments in comparative judgment tasks: The role of cognitive styles. *Personality and Individual Differences* **38**:1701–1713.

Bland, M.J. and Altman, D. (1986). Statistical Methods for Assessing Agreement Between Two Methods of Clinical Measurement. *The Lancet* **327**:307–310.

Boksem, M.A.S. and Tops, M. (2008). Mental fatigue: Costs and benefits. *Brain Research Reviews* [Online] **59**:125–139. Available at: http://dx.doi.org/10.1016/j.brainresrev.2008.07.001.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales.* Human kinetics.

Borin, J.P. *et al.* (2013). The distances covered by basketball referees in a match increase throughout the competition phases, with no change in physiological demand. *Open access journal of sports medicine* [Online] **4**:193–198. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3871407&tool=pmcentrez&rendertype=abstract.

Brand, R., Plessner, H. and Schweizer, G. (2009). Conceptual considerations about the development of a decision-making training method for expert soccer referees. *Perspectives on Congition and Action in Sport*:181–190.

Brisswalter, J., Callardeau, M. and René, A. (2002). Effects of acute physical exercise on cognitive performance. *Sports medicine (Auckland, N.Z.)* **32**:555–566.

Burns, T.I.M. (2003). Holistic Futsal a Total Mind-Body-Spirit Approach.

Casajus, J.A. and Castagna, C. (2007). Aerobic fitness and field test performance in elite Spanish soccer referees of different ages. *Journal of Science and Medicine in Sport* **10**:382–389.

Castagna, C. *et al.* (2009). Match demands of professional Futsal: A case study. *Journal of Science and Medicine in Sport* **12**:490–494.

Castagna, C., Abt, G. and D'ottavio, S. (2004). Activity profile of international-level soccer referees during competitive matches. *The Journal of Strength & Conditioning Research* **18**:486–490.

Castagna, C., Abt, G. and D'ottavio, S. (2007). Physiological aspects of soccer refereeing performance and training. *Sports medicine* **37**:625–646.

Castagna, C., Abt, G. and D'ottavio, S. (2002). Relation Between Fitness Tests and Match Performance in Elite Italian Soccer Referees. *Journal of Strength and Conditioning Research* [Online] **16**:231–235. Available at: http://content.wkhealth.com/linkback/openurl?sid=WKPTLP:landingpage&an=00124278-200205000-00010.

Castagna, C., Abt, G. and D'Ottavio, S. (2005). Competitive-level differences in Yo-Yo intermittent recovery and twelve minute run test performance in soccer referees. *Journal of strength and conditioning research / National Strength & Conditioning Association* **19**:805–809.

Castagna, C. and D'ottavio, S. (2001). Effect of maximal aerobic power on match performance in elite soccer referees. *Journal of strength and conditioning research / National Strength & Conditioning Association* **15**:420–425.

Castillo, D. *et al.* (2016). Physical fitness and physiological characteristics of soccer referees. *Science and Sports* [Online] **31**:27–35. Available at: http://dx.doi.org/10.1016/j.scispo.2015.11.003.

Catteeuw, P., Helsen, W., Gilis, B. and Wagemans, J. (2009). Decision-making skills, role specificity, and deliberate practice in association football refereeing. *Journal of Sports Sciences* [Online] **27**:1125–1136. Available at: http://www.tandfonline.com/doi/abs/10.1080/02640410903079179.

Catteeuw, P., Gilis, B., García-Aranda, J.-M., *et al.* (2010). Offside decision making in the 2002 and 2006 FIFA World Cups. *Journal of Sports Sciences* [Online] **28**:1027–1032. Available at: http://www.tandfonline.com/doi/abs/10.1080/02640414.2010.491084.

Catteeuw, P., Gilis, B., Wagemans, J., *et al.* (2010a). Offside decision making of assistant referees in the English Premier League: Impact of physical and perceptual-cognitive factors on match performance. *Journal of Sports Sciences* [Online] **28**:471–481. Available at: http://www.tandfonline.com/doi/abs/10.1080/02640410903518184.

Catteeuw, P., Gilis, B., Wagemans, J., *et al.* (2010b). Perceptual-cognitive skills in offside decision making: Expertise and training effects. *Journal of Sport and Exercise Psychology* [Online] **32**:828–844. Available at: http://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=57956852&site=ehost-live%5Cnhttp://www.tandfonline.com/doi/abs/10.1080/02640414.2010.491084%5Cnhttp://journals.humankinetics.com/doi/10.1123/jsep.32.6.845.

Catteeuw, P., Helsen, W., Gilis, B., Van Roie, E., *et al.* (2009). Visual scan patterns and decision-making skills of expert assistant referees in offside situations. *Journal of* *sport & exercise psychology* **31**:786–797.

Catterall, C. *et al.* (1993). Analysis of the work rates and heart rates of association football referees. *British journal of sports medicine* [Online] **27**:193–196. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1332186&tool=pmcentrez&rendertype=abstract.

Causer, J. and Ford, P.R. (2014). 'Decisions, decisions, decisions': Transfer and specificity of decision-making skill between sports. *Cognitive Processing* **15**:385–389.

Chang, Y.K. *et al.* (2012). The effects of acute exercise on cognitive performance: A meta-analysis. *Brain Research* [Online] **1453**:87–101. Available at: http://dx.doi.org/10.1016/j.brainres.2012.02.068.

Chmura, J. *et al.* (1998). Psychomotor performance during prolonged exercise above and below the blood lactate threshold. *European Journal of Applied Physiology and Occupational Physiology* **77**:77–80.

Chmura, J. and Nazar, K. (2010). Parallel changes in the onset of blood lactate accumulation (OBLA) and threshold of psychomotor performance deterioration during incremental exercise after training in athletes. *International Journal of Psychophysiology* [Online] **75**:287–290. Available at: http://dx.doi.org/10.1016/j.ijpsycho.2009.12.011.

Costa, E.C. *et al.* (2013). Monitoring external and internal loads of Brazilian soccer referees during official matches. *Journal of Sports Science and Medicine* **12**:559–564.

Van Cutsem, J. *et al.* (2017). The effects of Mental Fatigue on Physical Performance: A Systematic Review. *Sports Medicine* **47**:1569–1588.

D'ottavio, S. and Castagna, C. (2001a). Analysis of match activities in elite soccer referees during actual match play. *The Journal of Strength & Conditioning Research* **15**:167–171.

D'ottavio, S. and Castagna, C. (2001b). Physiological load imposed on elite soccer referees during actual match play. *Journal of Sports Medicine and Physical Fitness* **41**:27–32.

Dinges, D.F. and Powell, J.W. (1985). Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. *Behavior Research Methods, Instruments, & Computers* **17**:652–655.

Dinges, J.D.F. *et al.* (1997). Cumulative Sleepiness, Mood Disturbance, and Psychomotor Vigilance Performance Decrements During a Week of Sleep Restricted to 4–5 Hours per Night. *Sleep* [Online] **20**:267–277. Available at: https://academic.oup.com/sleep/article/20/4/267/2732104/Cumulative-Sleepiness-Mood-Disturbance-and.

Dixon, D. (2014a). A Pilot Study of the Physiological Demands of Futsal Referees Engaged in International Friendly Matches. *American Journal of Sport Science and Medicine* **2**:103–107.

Dixon, D. (2014b). A Retrospective Study of the Yo-Yo IE2 Test: Can It be Used to Differentiate Between Different Levels of Futsal Referees? *American Journal of Sports Science and Medicine* [Online] **2**:93–97. Available at: http://pubs.sciepub.com/ajssm/2/3/5/index.html.

Dixon, D. (2014c). An examination of the relationship between decision making and hydration status in Futsal Referees. In: *Book of Abstracts*. pp. 22–23.

Dogramaci, S.N., Watsford, M.L. and Murphu, A.J. (2011). Time-motion analysis of international and national level futsal. *The Journal of Strength & Conditioning Research* **25**:646–651.

Doğramacı, S.N. and Watsford, M.L. (2006). A comparison of two different methods for time-motion analysis in team sports. *International Journal of Performance Analysis in Sport* **6**:73–83.

Dohmen, T.J. (2008). The influence of social forces: Evidence from the behavior of football referees. *Economic Inquiry* **46**:411–424.

Doran, S.M., Van Dongen, H.P.A. and Dinges, D.F. (2001). Sustained attention performance during sleep deprivation: evidence of state instability. *Archives Italiennes de Biologie* **139**:253–267.

Dorrian, J., Rogers, N.L. and Dinges, D.F. (2005). Psychomotor vigilance performance: Neurocognitive assay sensitive to sleep loss. In: *Sleep Deprivation: Clinical Issues, Pharmacology and Sleep Loss Effects*. pp. 39–70.

Drust, B., Reilly, T. and Cable, N.T. (2000). Physiological responses to laboratory-based soccer-specific intermittent and continuous exercise. *Journal of sports sciences* [Online] **18**:885–892. Available at: http://www.tandfonline.com/doi/abs/10.1080/026404100750017814.

Ekblom, B. (1986). Applied Physiology of Soccer. *Sports Medicine* **3**:50–60.

Ellemberg, D. and St-Louis-Deschênes, M. (2010). The effect of acute physical exercise on cognitive function during development. *Psychology of Sport and Exercise* **11**:122–126.

Elsworthy, N., Burke, D. and Dascombe, B.J. (2014). Factors relating to the decision-making performance of Australian football officials. *International Journal of Performance Analysis in Sport* [Online] **14**:401–410. Available at: http://www.evolutionarycognition.org/papers/Elsworthy et al. (2014) Edited Proof.pdf.

Elsworthy, N., Burke, D. and Dascombe, B.J. (2016). Physical and psychomotor performance of Australian football and rugby league officials during a match simulation. *Journal of sports sciences* [Online] **34**:420–428. Available at: http://dx.doi.org/10.1080/02640414.2015.1057208.

Elsworthy, N. and Dascombe, B.J. (2011). The match demands of Australian rules football umpires in a state-based competition. *International Journal of Sports Physiology and Performance* **6**:559–571.

Fédération Internationale de Football Association (FIFA) (2015). *FIFA Executive Vows to Improve Governance and Boost Female Participation in Football* [Online]. Available at: http://www.fifa.com/about-fifa/news/y=2015/m=9/news=fifa-executive-vows-to-improve-governance-and-boost-female-participati-2696406.html.

Fédération Internationale de Football Association (FIFA) (2016a). *FIFA Quiz, FIFA World Cup Brazil 2014* [Online]. Available at: https://www.labhipermedia.net/downloads/2016/04/29/mens-competitions-in-2014-analysis-of-match-situations/.

Fédération Internationale de Football Association (FIFA) (2016b). *Fitness Test for Referees (Men & Women)* [Online]. Available at: http://resources.fifa.com/mm/document/affederation/administration/02/82/17/33/circ ularno.1551-2017fifarefereeinginternationallists_neutral.pdf.

Fédération Internationale de Football Association (FIFA) (2014). *Futsal Laws of the Game 2014/15* [Online]. Available at: http://resources.fifa.com/mm/document/footballdevelopment/refereeing/51/44/50/lawsofthegamefutsal2014_15_eneu_neutral.pdf [Accessed: 1 August 2017].

Fédération Internationale de Football Association (FIFA) (2017). *Laws of the Game 2017/18* [Online]. Available at: http://resources.fifa.com/mm/document/footballdevelopment/refereeing/02/90/11/67/lawsofthegame2017-2018-en_neutral.pdf.

Fédération Internationale de Football Association (FIFA) (2010). *Regulations on the Organisation of Refereeing in FIFA Member Associations* [Online]. Available at: https://resources.fifa.com/mm/document/tournament/competition/01/28/10/42/defs_regulationsorganisationrefereeinginfifama_inhalt.pdf.

Foster, C. *et al.* (2001). A New Approach to Monitoring Exercise Training. *Journal of Strength and Conditioning Research* **15**:109–115.

Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. *Medicine and science in sports and exercise* **30**:1164–1168.

Gabbet, T.J. and Mulvey, M.J. (2008). Time-motion analysis of small-sided training games and competition in elite women soccer players. *Journal of Strength and Conditioning Research* **22**:543–552.

Gabbett, T.J. *et al.* (2014). Influence of field position and phase of play on the physical demands of match-play in professional rugby league forwards. *Journal of Science and Medicine in Sport* [Online] **17**:556–561. Available at: http://dx.doi.org/10.1016/j.jsams.2013.08.002.

Galan, P.Á. (2016). AFC Futsal Referees Seminar (1-4 November).

Gallardo, M.A., Iglesias, A.J.B. and Quintana, M.S. (2009). Advantages of applying video to interactive auto-evaluation: A model used for the training of referees and instructors of the Fédération Internationale of Football Association (FIFA) and the Union of European Football Associations (UEFA). *Proceedings of the 5th IASTED European Conference on Internet and Multimedia Systems and Applications, EuroIMSA 2009* [Online]:62–65. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-74549160312&partnerID=40&md5=1d92c620f4466a32d451337d9571d487.

Gilis, B. *et al.* (2008). Offside decisions by expert assistant referees in association football: Perception and recall of spatial positions in complex dynamic events. *Journal of Experimental Psychology: Applied* [Online] **14**:21–35. Available at: http://doi.apa.org/getdoi.cfm?doi=10.1037/1076-898X.14.1.21.

Gilman, S. *et al.* (1979). Effects of Exercise Stress on Parotid Gland Secretion. *Hormone and Metabolic Research* [Online] **11**:454–454. Available at: http://www.thieme-connect.de/DOI/DOI?10.1055/s-0028-1095789.

Del Giorno, J.M. *et al.* (2010). Cognitive function during acute exercise: a test of the transient hypofrontality theory. *Journal of sport & exercise psychology* **32**:312–323.

Gopinathan, P.M., Pichan, G. and Sharma, V.M. (1988). Role of dehydration in heat stress-induced variations in mental performance. *Archives of environmental health* **43**:15–17.

Gray, A. and Jenkins, D. (2010). Match analysis and the physiological demands of Australian football. *Sports Medicine* [Online] **40**:347–360. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20364877.

Halperin, J.M. *et al.* (1991). Assessment of the Continuous Performance Test: Reliability and validity in a nonreferred sample. *A Journal of Consulting and Clinical Psychology* **3**:603.

Harley, R.A., Banks, R. and Doust, J. (2002). The development and evaluation of a task specific fitness test for association football referees. In: Routledge ed. *Science and Football IV*. London and New York: London: Routledge, pp. 76–80.

Harley, R.A., Tozer, K. and Doust, J. (2001). An analysis of movement patterns and physiological strain in relation to optimal positioning of association football referees. In: Routledge ed. *Science and Football IV*. London and New York, pp. 137–143.

Harrison, Y. and Horne, J.A. (2000). The impact of sleep deprivation on decision making: A review. *Journal of Experimental psychology. Applied* **6**:236–249.

Al Hazmi, A.D. (2016). *The Movement and Positioning of Soccer Officials in Relation to Their Decision Making*.

Helsen, W. and Bultynck, J.-B. (2004). Physical and perceptual-cognitive demands of top-class refereeing in association football. *Journal of sports sciences* **22**:179–189.

Helsen, W., Gilis, B. and Weston, M. (2006). Errors in judging 'offside' in association football: test of the optical error versus the perceptual flash-lag hypothesis. *Journal of sports sciences* [Online] **24**:521–528. Available at: http://www.tandfonline.com/doi/pdf/10.1080/02640410500298065?needAccess=true.

Herman, L. *et al.* (2006). Validity and reliability of the session rPe method for monitoring exercise training intensity. *South African Journal of Sports Medicine* **18**:14–17.

Hermans, V. and Engler, R. (2010). *Futsal: Technique, Tactics, Training*. Meyer & Meyer Verlag.

Hopkins, W.G. (2001). *A New View of Statistics*.

Hopkins, W.G. (2000). Measures of Reliability in Sports Medicine and Science. *Sports Medicine* [Online] **30**:375–381. Available at: http://link.springer.com/10.2165/00007256-200030050-00006.

Houssein, M. *et al.* (2016). Hydration: The new FIFA world cup's challenge for referee decision making? *Journal of Athletic Training* **51**:264–266.

Impellizzeri, F.M. *et al.* (2004). Use of RPE-Based Training Load in Soccer. *Medicine & Science in sports & exercise* **36**:1042–1047.

Janelle, christopher M., Singer, R.N. and Williams, A.M. (1992). External distraction and attentional narrowing: Visual search evidence. *Journal of Sport and Exercise Psychology* **21**:70–91.

Jewett, M. *et al.* (1999). Dose–response relationship between sleep duration and human psychomotor vigilance and subjective alertness? *Sleep* [Online] **22**:171–179. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20431354.

Johnston, L. and McNaughton, L. (1994). The physiological requirements of Soccer refereeing. *Australian journal of science and medicine in sport* **26**:67–72.

Kashihara, K. *et al.* (2009). Positive Effects of Acute and Moderate Physical Exercise on Cognitive Function. *Journal of PHYSIOLOGICAL ANTHROPOLOGY* [Online]

28:155–164. Available at: http://joi.jlc.jst.go.jp/JST.JSTAGE/jpa2/28.155?from=CrossRef.

Killgore, W.D.S., Balkin, T.J. and Wesensten, N.J. (2006). Impaired decision making following 49 hours of sleep deprivation. *Journal of Sleep Research* [Online] **15**:7–13. Available at: http://dx.doi.org/10.1111/j.1365-2869.2006.00487.x%5Cnhttp://www3.interscience.wiley.com/cgi-bin/fulltext?ID=118589606&PLACEBO=IE.pdf&mode=pdf.

Klass, M. *et al.* (2012). Effects of noradrenaline and dopamine on supraspinal fatigue in well-trained men. *Medicine and Science in Sports and Exercise* **44**:2299–2308.

Krustrup, P. *et al.* (2009). Activity profile and physical demands of football referees and assistant referees in international games. *Journal of sports sciences* [Online] **27**:1167–1176. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19705329.

Krustrup, P. and Bangsbo, J. (2001). Physiological demands of top-class soccer refereeing in relation to physical capacity: effect of intense intermittent exercise training. *Journal of Sports Sciences* [Online] **19**:881–891. Available at: http://www.tandfonline.com/doi/abs/10.1080/026404101753113831.

Krustrup, P., Mohr, M. and Bangsbo, J. (2002). Activity profile and physiological demands of top-class soccer assistant refereeing in relation to training status. *Journal of Sports Sciences* [Online] **20**:861–871. Available at: http://www.tandfonline.com/doi/abs/10.1080/026404102320761778.

Lambourne, K. and Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: A meta-regression analysis. *Brain Research* [Online] **1341**:12–24. Available at: http://dx.doi.org/10.1016/j.brainres.2010.03.091.

Lamond, N., Dawson, D. and Roach, G.D. (2005). Fatigue assessment in the field: Validation of a hand-held electronic psychomotor vigilance task. *Aviation Space and Environmental Medicine* **76**:486–489.

Loh, S. *et al.* (2004). The validity of psychomotor vigilance tasks of less than 10-minute duration. *Behavior research methods, instruments & computers* **36**:339–346.

Lovell, G., Newell, R. and Parker, J. (2014). Referees' Decision Making Behavior and the Sport Home Advantage Phenomenon. *Research in Psychology and Behavioral Sciences* [Online] **2**:1–5. Available at: http://pubs.sciepub.com/rpbs/2/1/1/.

MacMahon, C. *et al.* (2007). Decision-making skills and deliberate practice in elite association football referees. *Journal of sports sciences* [Online] **25**:65–78. Available at: http://www.tandfonline.com/doi/abs/10.1080/02640410600718640.

MacMahon, C. *et al.* (2014). *Sports Officials and Officiating: Science and Practice*. London and New York: Routledge.

Makaje, N. *et al.* (2012). Physiological demands and activity profiles during futsal match play according to competitive level. *The Journal of sports medicine and physical fitness* **52**:366–374.

Mallo, J. *et al.* (2009a). Activity profile of top-class association football referees in relation to fitness-test performance and match standard. *Journal of sports sciences* [Online] **27**:9–17. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18979338.

Mallo, J. *et al.* (2007). Activity profile of top-class association football referees in relation to performance in selected physical tests. *Journal of sports sciences* [Online] **25**:805–813. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18979338.

Mallo, J. *et al.* (2010). Activity profile of top-class female soccer refereeing in relation to the position of the ball. *Journal of Science and Medicine in Sport* **13**:129–132.

Mallo, J. *et al.* (2008). Analysis of the kinematical demands imposed on top-class assistant referees during competitive soccer matches. *Journal of Strength and Conditioning Research* [Online] **22**:235–242. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-41649116289&partnerID=40&md5=86aa63a0c54b3d22c2926da44ef3f977.

Mallo, J. *et al.* (2012). Effect of positioning on the accuracy of decision making of association football top-class referees and assistant referees during competitive matches. *Journal of sports sciences* [Online] **30**:1437–1445. Available at: http://www.tandfonline.com/doi/abs/10.1080/02640414.2012.711485.

Mallo, J. *et al.* (2009b). Physical demands of top-class soccer assistant refereeing during high-standard matches. *International Journal of Sports Medicine* **30**:331–336.

Manzi, V. *et al.* (2010). Profile of weekly training load in elite male professional basketball players. *The Journal of Strength & Conditioning Research* **24**:1399–1406.

Marcora, S.M., Staiano, W. and Manning, V. (2009). Mental fatigue impairs physical performance in humans. *Journal of applied physiology* **106**:857–864.

Martin, K. *et al.* (2016). Superior inhibitory control and resistance to mental fatigue in professional road cyclists. *PLoS ONE* **11**:1–15.

Mascarenhas, D.R.D. *et al.* (2009). Physical Performance and Decision Making in Association Football Referees : A Naturalistic Study. *Open Sports Sciences Journal* **2**:1–9.

Maughan, R.. and Leiper, J.. (1994). Effects of carbohydrate feeding on mental functions during sustained physical work. *Journal of Sports Sciences* **12**:29–34.

Van Meerbeek, R., Van Gool, D. and Bollens, J. (1987). Analysis of the refereeing decisions during the world soccer championship in 1986 in mexico. In: *Science and Football. Proceedings of the First World Congress of Science and Football*. p. 384.

Mehta, R.K. and Parasuraman, R. (2013). Effects of Mental Fatigue on the Development of Physical Fatigue: A Neuroergonomic Approach. *Human Factors: The Journal of the Human Factors and Ergonomics Society* [Online] **56**:645–656. Available at: http://hfs.sagepub.com/cgi/doi/10.1177/0018720813507279.

Milanez, V.F. *et al.* (2011). The role of aerobic fitness on session rating of perceived exertion in futsal players. *International Journal of Sports Physiology and Performance* **6**:358–366.

Moreira, A. *et al.* (2012). Session RPE and salivary immune-endocrine responses to simulated and official basketball matches in elite young male athletes. *J Sports Med Phys Fitness* **52**:682–687.

Nater, U.M. *et al.* (2005). Human salivary alpha-amylase reactivity in a psychosocial stress paradigm. *International Journal of Psychophysiology* **55**:333–342.

De Oliveira, M.C. *et al.* (2008). Analysis of in- field displacement patterns and functional indexes of referees during the soccer match. *Fitness & Performance Journal* **7**:41–47.

Oudejans, R.R. *et al.* (2000). Errors in judging ‘offside’ in football. *Nature* **404**:33.

Oudejans, R.R.D. *et al.* (2005). *How Position and Motion of Expert Assistant Referees in Soccer Relate to the Quality of Their Offside Judgements during Actual Match Play*.

International Journal of Sport Psychology:3–21.

Pageaux, B. *et al.* (2014). Response inhibition impairs subsequent self‐paced endurance performance. *European journal of applied physiology* **114**:1095–1105.

Pageaux, B. (2014). The Psychobiological Model of Endurance Performance: An Effort-Based Decision-Making Theory to Explain Self-Paced Endurance Performance. *Sports Medicine* **44**:1319–1320.

Paradis, K., Larkin, P. and O'Connor, D. (2016). The effects of physical exertion on Decision-Making performance of Australian Football Umpires. *Journal of Sports Sciences* [Online] **34**:1535–1541. Available at: http://dx.doi.org/10.1080/02640414.2015.1122205.

Pietraszewski, P. *et al.* (2014). The Elements of Executive Attention in Top Soccer Referees and Assistant Referees. *Journal of Human Kinetics* [Online] **40**:235–243. Available at: http://www.degruyter.com/view/j/hukin.2014.40.issue-1/hukin-2014-0025/hukin-2014-0025.xml.

Plessner, H. and Haar, T. (2006). Sports performance judgments from a social cognitive perspective. *Psychology of Sport and Exercise* **7**:555–575.

Polidoro, L. *et al.* (2013). Futsal training by video analysis. *Journal of Human Sport and Exercise* **8**:290–296.

Put, K. *et al.* (2013). Web-based training improves on-field offside decision-making performance. *Psychology of Sport & Exercise* [Online] **14**:577–585. Available at: http://dx.doi.org/10.1016/j.psychsport.2013.03.005.

Rebelo, A.N. *et al.* (2011). Elite futsal refereeing: activity profile and physiological demands. *The Journal of Strength & Conditioning Research* **25**:980–987.

Reilly, T. *et al.* (1985). Effects of carbohydrate feeding on mental functions during sustained physical work. *Ergonomics international* **85**:700–702.

Reilly, T. and Gregson, W. (2006). Special populations: the referee and assistant referee. *Journal of sports sciences* [Online] **24**:795–801. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16766507.

Rienzi, E. *et al.* (2000). Investigation of anthropometric and work rate profiles of elite south american international soccer player. *Journal of Sports Medicine and Physical*

Fitness **40**:162.

Di Salvo, V., Carmont, M.R. and Maffulli, N. (2011). Football officials activities during matches: a comparison of activity of referees and linesmen in European, Premiership and Championship matches. *Muscles, ligaments and tendons journal* [Online] **1**:106–111. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3666476&tool=pmcentrez&rendertype=abstract.

Samuel, R.D. (2015). A Psychological Preparation Framework for Elite Soccer Referees: A Practitioner's Perspective. *Journal of Sport Psychology in Action* [Online] **6**:170–187. Available at: http://www.tandfonline.com/doi/full/10.1080/21520704.2015.1065938.

Schweizer, G. *et al.* (2011). A Video-Based Training Method for Improving Soccer Referees' Intuitive Decision-Making Skills. *Journal of Applied Sport Psychology* **23**:429–442.

Seicean, S. *et al.* (2011). An exploration of differences in sleep characteristics between Mexico-born US immigrants and other Americans to address the Hispanic Paradox. *Sleep* [Online] **34**:1021–1031. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3138157&tool=pmcentrez&rendertype=abstract%5Cnpapers3://publication/doi/10.5665/SLEEP.1154%5Cnfile:///Users/Dmello/OneDrive/Articles/An exploration of differences in sleep characteristics between Mexic.

Da Silva, a I. and Fernandez, R. (2003). Dehydration of football referees during a match. *British journal of sports medicine* **37**:502–506.

Da Silva, A.I. *et al.* (2013). Concentration and accuracy level of soccer referees during match. *Motricidade* **9**:13–22.

Da Silva, A.I., Fernandes, L.C. and Fernandez, R. (2008). Energy expenditure and intensity of physical activity in soccer referees during match-play. *Journal of Sports Science and Medicine* **7**:327–334.

Da Silva, A.I., Fernandes, L.C. and Fernandez, R. (2011). Time motion analysis of football (soccer) referees during official matches in relation to the type of fluid consumed. *Brazilian Journal of Medical and Biological Research* **44**:801–809.

Slack, L. a. *et al.* (2013). Factors Underpinning Football Officiating Excellence: Perceptions of English Premier League Referees. *Journal of Applied Sport Psychology* **25**:298–315.

Strauss, G.P. *et al.* (2005). Test-retest reliability of standard and emotional Stroop tasks: An investigation of color-word and picture-word versions. *Assessment* **12**:330–337.

Strauss, M.E. *et al.* (2014). Temporal stability and moderating effects of age and sex on CNTRaCS task performance. *Schizophrenia Bulletin* **40**:835–844.

Suppiah, H.T., Low, C.Y. and Chia, M. (2016). Effects of sport-specific training intensity on sleep patterns and psychomotor performance in adolescent athletes. *Pediatric exercise science* **28**:588–595.

Surujlal, J. and Jordaan, D.B. (2013). Goal line technology in soccer: Are referees ready for technology in decision making. *African Journal for Physical, Health Education, Recreation and Dance* [Online] **19**:245–257. Available at: http://search.ebscohost.com/login.aspx?direct=true&AuthType=cookie,ip,shib&db=awn&AN=ajpherd-89820&site=ehost-live%5Cnhttp://www.ajol.info/index.php/ajpherd/article/view/89820.

Taylor, L. *et al.* (2014). Exposure to hot and cold environmental conditions does not affect the decision making ability of soccer referees following an intermittent sprint protocol. *Frontiers in Physiology* **5**:1–9.

Terry, P.C., Lane, A.M. and Fogarty, G.J. (2003). Construct validity of the Profile of Mood States - Adolescents for use with adults. *Psychology of Sport and Exercise* **4**:125–139.

Thorne, D.R. *et al.* (2005). The Walter Reed palm-held psychomotor vigilance test. *Behavior research methods* **37**:111–118.

Tilley, A.J. and Wilkinson, R.T. (1984). The effects of a restricted sleep regime on the composition of sleep and on performance. *Psychophysiology* **21**:406–412.

Tomporowski, P.D. (2003). Effects of acute bouts of exercise on cognition. *Acta Psychologica* **112**:297–324.

Tomporowski, P.D. and Ellis, N.R. (1986). Effects of exercise on cognitive processes: A review. *Psychological Bulletin* [Online] **99**:338–346. Available at: http://doi.apa.org/getdoi.cfm?doi=10.1037/0033-2909.99.3.338.

Unkelbach, C. and Memmert, D. (2010). Crowd noise as a cue in referee decisions contributes to the home advantage. *Journal of Sport & Exercise Psychology* **32**:483–498.

Verheijen, R. *et al.* (1999). Factors affecting decision-making of soccer referees. *Journal of Sports Sciences* **17**:832.

Wallace, L. k., Slattery, K.M. and Coutts, A.J. (2009). The ecological validity and application of the session-RPE method for quantifying training loads in swimming. *he Journal of Strength & Conditioning Research* **23**:33–38.

Watkins, S.L. *et al.* (2014). The Effect of Different Environmental Conditions on the Decision-making Performance of Soccer Goal Line Officials. *Research in Sports Medicine* **22**:425–437.

Weston, M. *et al.* (2010). Ageing and physical match performance in English Premier League soccer referees. *Journal of Science and Medicine in Sport* **13**:96–100.

Weston, M. *et al.* (2007). Analysis of physical match performance in English Premier League soccer referees with particular reference to first half and player work rates. *Journal of Science and Medicine in Sport* **10**:390–397.

Weston, M., Batterham, A.M., *et al.* (2011). Reduction in physical match performance at the start of the second half in elite soccer. *International Journal of Sports Physiology and Performance* **6**:174–182.

Weston, M. *et al.* (2009). Relationships among field-test measures and physical match performance in elite-standard soccer referees. *Journal of Sports Sciences* **27**:1177–1184.

Weston, M. *et al.* (2012). Science and Medicine Applied to Soccer Refereeing An Update. *Sports Medicine* **42**:615–631.

Weston, M. *et al.* (2006). The effect of match standard and referee experience on the objective and subjective match workload of English Premier League referees. *Journal of Science and Medicine in Sport* **9**:256–262.

Weston, M., Drust, B., *et al.* (2011). Variability of Soccer Referees' Match Performances. *International Journal of Sports Medicine* **32**:190–194.

Weston, M. and Brewer, J. (2002). A study of the physiological demands of soccer refereeing. *Journal of Sports Sciences* **20**:59–60.

Weston, M., Drust, B. and Gregson, W. (2011). Intensities of exercise during match-play in FA Premier League referees and players. *Journal of Sports Sciences* **29**:527–532.

Wilkinson, M. (2014). Distinguishing between statistical significance and practical/clinical meaningfulness using statistical inference. *Sports Medicine* **44**:295–301.

Wiśnik, P. *et al.* (2011). The effect of branched chain amino acids on psychomotor performance during treadmill exercise of changing intensity simulating a soccer game. *Applied Physiology, Nutrition, and Metabolism* [Online] **36**:856–862. Available at: http://www.nrcresearchpress.com/doi/abs/10.1139/h11-110.

Witzig, R. (2006). *The Global Art of Soccer*. [Online]. New Orleans, LA: CusiBoy Publishing. Available at: https://books.google.co.uk/books?hl=en&lr=&id=H2T0ZD5S86QC&oi=fnd&pg=PR7&dq=The+global+art+of+soccer&ots=iGyyazWA0T&sig=PWJHLEYExhKnL924_jfn80ib28M#v=onepage&q=The global art of soccer&f=false.

Appendices

Appendix 1

Ethical clearance

Ethic Committee Approval by the University of Kent (Sport & Exercise Sciences) with the Ethic Reference Number for each study.

Chapter Ethics number University

Chapter	Ethics number	University
4 (1^{st} study)	**Prop 159_2013_14**	**Kent (cooperation with Iraqi Futsal Committee and University of Sulaimani)**
5 (3^{rd} study - pilot)	**Prop 100_2014_15**	**Kent (cooperation with Kent FA)**
6 (2^{nd} study)	**Prop 100_2014_15**	**Kent (cooperation with the FA)**
7 (3^{rd} study)	**Prop 139_2014_15**	**Kent (cooperation with Kent FA)**

Appendix 2

Kurdistan Regional government
Council of Ministers
Ministry of Health
D.O.H. in Sulaymani
Infection Control Dep.

هەرێمی کوردستانی عێراق
ئەنجومەنی وەزیران
وەزارەتی تەندروستی
بەڕێوەبەرایەتی گشتی تەندروستی سلێمانی
بەشی کۆنترۆڵ کردنی پیس بوون لە
دەرگانە تەندروستیەکان

No: 10944
Date: 6-7-2014

ژمارە: ١٠٩٤٤
بەروار: ٦ / ٧ / ٢٠١٤

TO/ University of Kent- school of sport and Exercise Science
Sub. / Elimination

Referring to the letter numbered 7/22/948 dated 17/6/2014 from faculty of physical education. we would like to inform you that two boxes of blood lactate related to high degree student (Hawkar Salar Ahmed) were incinerated in Sulaimaniyah directory of health incinerator in Tanjaro region

We refreshed him by this certificate upon his request.

Best Regards

KURDISTAN REGION
D.O.H Sulaimaniya

Dr. Miran Muhammad Abbas
General Health Director
miran_mirawdaly@hotmail.com
Mobile No: +9647701580748

Email: Tandrusti.sul@gmail.com
Tel: 0533207011

Appendix 3

FIFA Pemission

From: Contact (FIFA) [contact@fifa.org]
Sent: 23 July 2014 16:55
To: H.S.A.Ahmed
Subject: RE: FIFA's laws of the game Quiz DVD

Dear Hawkar,

Thank you for your enquiry.

Please be informed that we don’t have a new laws of the game Quiz DVD for Futsal.

But we kindly advise you to the following website, where we provide all teaching materials as well as interactive questions about refereeing:

http://labhipermedia.net/descargas/

We trust this information will be of use to you.

Kind regards,

FIFA Communications & Public Affairs

Fédération Internationale de Football Association

FIFA-Strasse 20 P.O. Box 8044 Zurich Switzerland

Tel.: +41-(0)43-222 7777

contact@fifa.org

www.FIFA.com

www.youtube.com/fifatv

Appendix 4

Mood Questionnaire (BRUMS)

The Brunel Mood Scale (BRUMS)

Below is a list of words that describe feelings people have. Please read each one carefully. Then circle the answer (number) which best describes HOW YOU FEEL RIGHT NOW. Make sure you answer every question.

	Not at all	A little	Moderately	Quite a lot	Extremely
1. Panicky	0	1	2	3	4
2. Lively	0	1	2	3	4
3. Confused	0	1	2	3	4
4. Worn Out	0	1	2	3	4
5. Depressed	0	1	2	3	4
6. Downhearted	0	1	2	3	4
7. Annoyed	0	1	2	3	4
8. Exhausted	0	1	2	3	4
9. Mixed-Up	0	1	2	3	4
10. Sleepy	0	1	2	3	4
11. Bitter	0	1	2	3	4
12. Unhappy	0	1	2	3	4
13. Anxious	0	1	2	3	4
14. Worried	0	1	2	3	4
15. Energetic	0	1	2	3	4
16. Miserable	0	1	2	3	4
17. Muddled	0	1	2	3	4
18. Nervous	0	1	2	3	4
19. Angry	0	1	2	3	4
20. Active	0	1	2	3	4
21. Tired	0	1	2	3	4
22. Bad Tempered	0	1	2	3	4
23. Alert	0	1	2	3	4
24. Uncertain	0	1	2	3	4

Mood questionnaire scoring

Add items 1, 13, 14, and 18 for a Tension score.

Add items 5, 6, 12, and 16 for a Depression score.

Add items 7, 11, 19, and 22 for an Anger score.

Add items 2, 15, 20, and 23 for a Vigour score.

Add items 4, 8, 10, and 21 for a Fatigue score.

Add items 3, 9, 17, and 24 for a Confusion score.

Appendix 5

The FA permission

15th September 2015

DR G DAVISON

School of Sport & Exercise Sciences
University of Kent, Medway Campus, The Medway Building M0-26, Chatham Maritime, Kent, ME4 4AG

Direct Tel: 01934 876011

Direct Fax: 01934 876011

Dear Dr Davison

Futsal Referee Research

Thank you for your letter confirming your intention to use Hawkar Ahmed in carrying out the above research and involving the Football Association Futsal referees operating on the National League.

I confirm I am happy for you to approach referees before and after games to facilitate this research and understand you will also be obtaining individual referee's permission to carry out your work with them.

I hope the study is successful and look forward to receiving feedback in due course.

Yours sincerely

Roger Vaughan

National Referee Manager

Small Sided Football and Futsal

C.c Ian Blanchard

Appendix 6

A Randomization Plan

From: **http://www.randomization.com**

1. ____________________
    - Fatigue Group
    - Control Group
2. ____________________
    - Fatigue Group
    - Control Group
3. ____________________
    - Fatigue Group
    - Control Group
4. ____________________
    - Control Group
    - Fatigue Group
5. ____________________
    - Control Group
    - Fatigue Group
6. ____________________
    - Control Group
    - Fatigue Group
7. ____________________
    - Control Group
    - Fatigue Group
8. ____________________
    - Fatigue Group
    - Control Group
9. ____________________
    - Control Group
    - Fatigue Group
10. ____________________
    - Fatigue Group
    - Control Group

11. ______________________________

   - Fatigue Group
   - Control Group

12. ______________________________

   - Control Group
   - Fatigue Group

13. ______________________________

   - Control Group
   - Fatigue Group

14. ______________________________

   - Fatigue Group
   - Control Group

15. ______________________________

   - Control Group
   - Fatigue Group

16. ______________________________

   - Fatigue Group
   - Control Group

16 subjects randomized into 2 blocks

To reproduce this plan, use the seed 21113

Randomization plan created on 12/15/2015, 12:10:21 PM

Appendix 6

Name:
Visit:
Pre: ○ Post: ○

FIFA Incidents Answer Sheet

Clip 1 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 2 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 3 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 4 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 5 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 6 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 7 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 8 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 9 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card

Clip 10 ○

- ○ No foul / No offence
- ○ Indirect free kick
- ○ Direct free kick
- ○ Penalty kick

- ○ No card
- ○ Yellow card
- ○ Red card