THE UNIVERSITY OF HULL

The effect of a personal fluid delivery system on thermoregulation and physical performance during a soccer simulation.

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Abbreviations

Physiological Abbreviations:

PV – Plasma Volume

P_{Osm} – Plasma Osmolality

U_{Osm} – Urine Osmolality

HR – Heart Rate

SV – Stroke Volume

CV – Cardiovascular

HR_{max} – Maximal Heart rate

U_{SG} – Urine Specific Gravity

U_{Col} – Urine Colour

BM – Body Mass

TBW – Total Body Water

VT_1 – Ventilatory Threshold

VT_2 – Respiratory Compensation Threshold

VO_2max – Maximal Oxygen Consumption

Thermoregulatory abbreviations:

MBT – Mean Body Temperature

MST – Mean Skin Temperature

T_{rec} – Core Temperature

T_{sk} – Skin Temperature

T_c – Chest Temperature

T_b – Bicep Temperature

T_g – Gastrocnemius (calf) Temperature

Statistical Abbreviations

ES – Effect Size

CI – Confidence Interval

S – Small

M – Moderate

L – Large

T – Trivial

SD – Standard Deviation

Subjective Measure abbreviations:

RPE – Rate of Perceived Exertion

TC – Thermal Comfort

TS – Thermal Sensation

Performance Abbreviations:

PPO – Peak Power Output

MPO – Mean Power Output

HIA – High Intensity Activity

LSR – Low Speed Running

MSR – Moderate Speed Running

HSR – High Speed Running

MAS – Maximal aerobic speed

RSA – Repeated Sprint Ability

Other Abbreviations:

Km – Kilometres

PFDS – Personal Fluid Delivery System

HT – Half Time

FL – Fluid

DE – Dehydration

Contents:

Introduction: The requirements of soccer refereeing are physiologically demanding. As a consequence of these high physical demands and the relative inefficiency of the human body, the referee will generate a considerable amount of heat. Decreases in body fluid can result in reduced physical performance and increase thermoregulatory strain. This may be exacerbated when officiating in hot and humid conditions. When drinking only at half time referees do not intake sufficient amounts of fluid to replace fluid lost over the duration of a match. One possible solution for the soccer referee is to carry fluid with them in order to match fluid loss with fluid intake during the match. The purpose of this study was to investigate if a Personal Fluid Delivery System (PFDS) affected physical performance and thermoregulatory responses during a soccer specific simulation conducted in a hot and humid environment.

Methods: Using a repeated measures, randomly assigned crossover design, 14 male team sport players (Age 21 ± 2.1; VO_2max 54.5 ml•kg^{-1} ± 5.8) complete a 90 min soccer simulation in hot/humid (30ºC & 45% RH) conditions with and without a PFDS. Physical performance measures (peak and mean power output), hydration markers and thermoregulatory measures (body and skin temperature) were examined. Protocol intensities were individualised to each participant based on ventilatory thresholds obtained during a pre-trial VO_2max test.

Results: The main findings of the study were: 1) The use of a PFDS resulted in a very large effect upon fluid intake. 2) The use of a PFDS resulted in a moderate negative effect upon the hydration status of the players decreasing urine concentration.

Conclusion – The present study found that wearing a PFDS whilst performing in hot conditions greatly increases fluid intake. However, drinking solely at half-time provided enough protection from dehydration when players began exercise in a hydrated state.

Chapter 1

Introduction

1.1 Introduction:

Dehydration causes a marked decline in physiological function (Wendt, van Loon, & Lichtenbelt, 2007). Physical and cognitive performance decrements are among the many negative outcomes of dehydration along with dizziness, fainting and death (Keatinge, 2003). When body water loss exceeds water intake, a fluid imbalance occurs which will eventually lead to dehydration. Mild dehydration is experienced when there is a 1 - 2 % deficit in body water content, often observed through body mass (BM) variation. A body water deficit ≥ 2% is associated with a more severe form of dehydration, which is inversely related to physiological performance (Reilly & Korkusuz, 2008). Body temperature regulation between skin and the environment is influenced through biophysical components in the environment including ambient temperature, humidity and radiation, but is also influenced by internal temperatures (Sawka et al., 2007). Athletes who undertake prolonged exercise in hot and humid conditions are likely to develop symptoms of dehydration at a much faster rate than in thermoneutral conditions (Shirreffs et al., 2005).

High ambient temperatures of ~30ºC are associated with an increased thermoregulatory strain. Consequently, specific rehydration strategies are necessary to prevent or delay the onset of dehydration during exercise. In team sports there are often periodic breaks, usually halfway through the match, that present players and officials with the opportunity to rehydrate before continuing to exercise. However, during these breaks, players seldom sufficiently replace fluid loss and often return to the field of play with a negative fluid balance. It has been reported that soccer referees' fluid intake during the half-time interval only restores approximately a quarter of fluids lost through gastric emptying and sweating during match play (Da Silva & Fernandez, 2003). The 2014 FIFA World Cup in Brazil was the first major international soccer tournament to implement scheduled drinks breaks. FIFA (2011) have stated that additional breaks are considered when wet bulb globe temperature (WBGT) is above 32 °C. It is worth noting that it is not just referees that fail to hydrate adequately. Soccer players often start match play in a dehydrated state. Even though a lack of pre-match hydration is yet to be reported in referees, previous studies show that soccer referees and outfield players have comparable activity profiles and cover very similar distances (Bangsbo, 1994; Bangsbo, Norregaard, & Thorso, 1991; Castagna, Abt, & D'Ottavio, 2007), so it is necessary that both referees and players reach and maintain a euhydrated state, in order to negate or limit the physiological strain associated with dehydration.

Soccer referees' match activity profiles have been investigated to explore fatigue during match play. It is important to examine soccer player match activities and their variations through the level of competition and how this affects a referees' activity profile. Elite soccer referees cover on average between approximately 9.5 km and 13 km in a 90-minute match (Castagna, Abt, & D'Ottavio, 2004; D'Ottavio & Castagna, 2001; Johnston & McNaughton, 1994; Krustrup & Bangsbo, 2001; Weston, Castagna, Impellizzeri, Rampinini, & Abt, 2007). Similarly, referees physical performance decreases in the 2nd half of match play in comparison to the first 45 minutes (Weston et al., 2007). D'Ottavio and Castagna (2001) studied the match activities of elite soccer referees reporting a 4.1% decrement in total running distance in the 2nd half of match play through 96 games over 5 seasons of Serie A. The ability of the referee to maintain a high level of performance throughout the full 90 minute match (and in some cases 120 minutes) is crucial in elite soccer. There is evidence that the fatigue experienced by players has a considerable influence on more goals being scored in the final stages of a match (Reilly & Korkusuz, 2008). Much like soccer players, referee's often experience a performance decline in the final 15 minutes of each half due to fatigue (Reilly & Gregson, 2006).

Despite a variety of studies conducted on the physical demands placed on referees during match play, there is still little evidence examining referees physiological and thermoregulatory responses in a thermal environment. There are mixed findings on the effects of heat stress and hydration on cognitive performance. Although cognitive performance is not investigated in the present study, studies have suggested that increases in core temperature can lead to a reduction in mental performance (Wyon, Andersen, & Lundqvist, 1979). Referees have to make several decisions every minute while keeping an optimal distance between themselves and the ball (De Oliveira, Orbetelli, & De Barros Neto, 2011;

Mallo, Frutos, Juárez, & Navarro, 2012). Therefore, it is important that referees maintain fluid balance throughout the match, especially when performing in a hot and humid environment.

One solution to this problem is for referees to carry fluid with them during the course of a match. This has become possible due to the development of personal fluid delivery systems, such as the CamelBak. These systems are worn as a backpack or around the waist and are capable of storing many litres of fluid. Given that referees do not engage physically with players during a match there would be no health and safety issues with referees wearing such a device. These systems have previously been used in research as a way of hydrating subjects, particularly in cycling studies (Hue, Henri, Baillot, Sinnapah, & Uzel, 2014). However, there has been no studies reporting the effect of a personal fluid delivery system on performance or thermoregulatory responses.

The aims of the study were to investigate if the application of a personal fluid delivery system (PFDS) increased fluid intake when exercising in a hot and humid environment and to examine if the application of a PFDS had an effect on physical performance and thermoregulatory response during exercise in a hot and humid environment. It is hoped that this research can be used to enhance the performance of elite soccer referees at future major championships.

Chapter 2

Review of Literature

2.1 Background of soccer:

With just under 700 million people watching the 2014 FIFA World Cup Final (a global audience increase of 12% on the 2010 World Cup Final) from their homes (FIFA.com), there is a clear understanding that soccer is continually growing. As the world's most popular sport, the boosted financial power is starting to be recognised. With constantly growing financial incentives there is an increased impetus from elite clubs and national sides to perform at the highest level.

2.2 Considerations of physical load in soccer:

There is a great deal of research that has been carried out on the physiological demands of soccer (Bangsbo, Mohr, & Krustrup, 2006; Drust, Reilly, & Cable, 2000; Greig, Mc Naughton, & Lovell, 2006). It has been documented that soccer performance at the elite level places high physical and physiological demands on players (Stølen, Chamari, Castagna, & Wisløff, 2005). In the professional game understanding this load has become essential for creating training programmes, especially in relation to positional role. Changes in the tactical aspect of the game and advancements in technology have resulted in more detailed monitoring of the load players take on in match play through analysis of match activity profiles.

Activity profiles and intensity thresholds in soccer players have been well documented over the last decade with researchers using distance covered at specific intensities as one of the key physical aspects of soccer performance (Bangsbo et al., 1991; Bloomfield, Polman, & O'Donoghue, 2007; Di Salvo et al., 2007). Earlier research from Reilly and Williams (2003) reported that outfield players can cover a distance of between 8-12 km throughout the course of a 90-minute match. However, distance covered is not a great representation of the physiological stress experienced as more than 70% of activity is in the form of standing, walking and jogging (Krustrup & Bangsbo, 2001). Despite athletes spending a small proportion of time at a high intensity, elite midfield players perform at a mean of more than 75%

of their predicted maximum heart rate (HR) over 90-minutes (Bangsbo et al., 2006). This shows that there is a high physiological demand placed of an outfield player. However, it is important to look further into the positional roles of the players and the distances covered. Di Salvo et al. (2007) investigated the performance characteristics and positional roles. The data, collected from twenty Spanish Premier League and ten Champions League matches reported significant differences in distance covered between central midfield players and central defenders (12027 ± 625 m vs 10627 ± 893 m).

2.3 Physical aspects of refereeing:

Recent literature displays clear links between soccer refereeing and soccer player physical performance. Physical demands on the referee decrease with the level of competition officiated (Castagna et al., 2004). Despite this, it is still important to consider that many different aspects will influence the match and subsequently the referee's activity profile. A referee's performance is often influenced by the tactical approach of each team and also the level of competition (Weston et al., 2012). A more direct game plan will mean the ball will travel further causing the referee to cover an increased distance along with an increase in high intensity running (Mallo, Navarro, Aranda, & Helsen, 2009). It is suggested that the total distance covered by a referee over 90 minutes is similar to that of a central midfield player. It can be speculated that this is due to the concept that the central midfielder's job is to link between the attack and the defence (Castagna et al., 2007). Match activity data displayed in table 1 and table 2 shows there are similarities in the activity profiles experienced by referees and players due to the referees movements being dictated by the match.

Table 1 Match activity data for elite referees

	(Castagna et al., 2004)		(Barbero-Alvarez, Boullosa, Nakamura, Andrin, & Castagna, 2012)		(Mallo et al., 2009)	
Activities	**Speed (km·h-1)**	**Quantity (%)**	**Speed (km·h-1)**	**Quantity (%)**	**Speed (km·h-1)**	**Quantity (%)**
Standing	-	-	0 - 0.4	-	< 3.6	37.1
Walking	-	8.9	0.5 - 4	13.2	3.61 - 7.2	26.0
Jogging	-	-	-	-	7.21 - 13	20.2
Cruise/Run	-	-	-	-	13.01 - 18	8.9
LSR	< 13	43.5	4.1 - 8	30	-	-
MSR	13.1 - 18	22.8	8.1 - 13	30.8	-	-
HSR	18.1 - 24	11.4	13.1 - 18	18.7	> 18	7.7
Sprinting	> 24	3.3	> 18.1	6.7	-	-
Other	-	10.1	-	-	-	-

Key: LSR = Low Speed Running, MSR = Moderate Speed Running, HSR = High Speed Running

Table 2 Match activity for elite soccer outfield players

	(Rampinini et al., 2007)		(Vigne, Gaudino, Rogowski, Alloatti, & Hautier, 2010)		(Bradley et al., 2009)	
Activities	**Speed (km·h-1)**	**Quantity (%)**	**Speed (km·h-1)**	**Quantity (%)**	**Speed (km·h-1)**	**Quantity (%)**
Standing	< 0.7	3.9	-	-	0 - 0.6	5.6
Walking	0.7 - 7.2	57.1	< 5	38.9	0.7 - 7.1	59.3
Jogging	7.2 - 14.4	28.2	5 - 13	29.5	7.2 - 14.3	26.1
Cruising/Run	14.4 - 19.8	7.24	-	-	14.4 - 19.7	6.4
LSR	-	-	-	-	-	-
MSR	-	-	13 - 16	13.4	-	-
HSR	19.8 - 25.2	2.17	16 - 19	8.4	19.8 - 25.1	2.0
Sprinting	> 25.2	0.54	> 19	9.8	> 25.1	0.6

Key: LSR = Low Speed Running, MSR = Moderate Speed Running, HSR = High Speed Running

2.3.1 Repeated sprint ability

In soccer-specific literature, it is believed that the ability to reproduce sprints is a key measure of physical performance. Several studies assessing repeated sprint ability (RSA) before and after soccer matches have provided evidence showing a substantial decline in RSA, influenced by the development of fatigue (Krustrup et al., 2006; Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004). This reduction in RSA is also important in top-level officiating as referees' physical performance is influenced by those of the players' during match play (Weston et al., 2007).

2.4 Physiological responses to refereeing:

2.4.1 Heart rate

The cardiovascular strain placed on a referee during match play is considered to be very high. Studies assessing heart rate (HR) in referees during a full match have shown that ~85% of age-predicted maximal heart rate (HR_{max}) is attained throughout the duration of the match (Krustrup & Bangsbo, 2001; Weston, Bird, Helsen, Nevill, & Castagna, 2006). The variation in distance covered during a match can be dependent on the level of competition and experience of the referee, which can lead to a lower skilled referee taking on an increased physiological load (Castagna et al., 2004).

The increase in HR during exercise is controlled through the autonomic nervous system. The initial buffering of the parasympathetic branch, followed by activation of the sympathetic system, facilitates an increase in HR. However, the nature of the referee's response before and during match-play stimulus may influence specific stress mediators, such as the neuro-endocrinal hormone release. The release of hormones, such as epinephrine, norepinephrine and other substrates, through the endocrinal response during moments of stress or fear lead to elevated HR during performance (Chrousos, 2009).

2.4.3 Age-related performance in referees

Declines in the functional capacity of the human body can begin at around 25 years of age (Shephard, 1997). Reduced muscle mass and strength is one of the physiological outcomes of the ageing process (Keller & Engelhardt, 2013). Muscle strength is understood to not have an impact on sprint performance (Alemdaroglu, 2012) however, previous research has shown that lower extremity muscle mass is positively correlated with sprint performance (Kumagai et al., 2000; Perez-Gomez et al., 2008).

As previously mentioned, soccer referees have been reported to have similar match activities to the players they are officiating. This means that referees are covering similar distances at specific intensities despite the average age being far higher. Weston, Castagna, Impellizzeri, Rampinini, and Breivik (2010) investigated the effect that age had on soccer referees' physical performance looking specifically at running performance and the referee's distance from the ball and fouls during match play. The researchers examined 26 English Premier League referees (age range 31-48 years) over four seasons. The study concluded that despite a reduced physical capacity associated with age, this had no influence on the referees' ability to keep up with the run of play. Since this study, the retirement age for referees (45 years) has been abolished resulting in referees beyond this age officiating at the highest level. Weston and colleagues research shows similar findings to Castagna, Abt, and D'Ottavio (2005) where HR_{max} was far lower in the older group of referees compared to the young group (176 $\pm$ 5 vs 189 $\pm$ 4; $P < 0.05$). It has previously been reported that age has an influence on physiological responses in hot conditions. Kenney et al. (1990) investigated the effect of hot environment on men of different age groups (22-28 vs 49-60 years). Results showed that there was an increased forearm blood flow in the younger group. It is understood that skin blood flow increases during heat stress in an attempt to reduce core temperature through sweating (Charkoudian, 2003). Therefore, it is necessary for older referees to focus on maintain a hydrated state during exercise to prevent hyperthermia.

2.5 Hydration in soccer:

2.5.1 Overview of hydration

Fluid consumption is an important aspect of sport and exercise that should be considered before, after and during exercise to avoid dehydration (Sawka et al., 2007). Dehydration can be defined as excessive body water loss below the basal level (Thomas et al., 2008), although it can be assessed using many methods. Body water is lost through sweat (when exercising), urine, faeces and through breathing which causes a reduction in total body water (TBW). Dehydration causes negative physiological outcomes and decreases performance levels and comes with several symptoms (Dizziness, Tiredness, headache). The risk of reduced physical capacity, physiological performance and cardiovascular function are all likely to occur without adequate fluid intake (Armstrong et al., 1997; Cheuvront, Kenefick, Charkoudian, & Sawka, 2013; Gonzalez-Alonso, Calbet, & Nielsen, 1998). Several factors have been reported to have an influence on fluid intake (Table 1).

Table 3. Factors influencing fluid intake (Hawley & Burke, 1998)

Factors influencing fluid intake
• Thirst • Awareness of sweat loss • Fluid availability • Opportunities to drink • Fluid palatability • Gastrointestinal discomfort • Awareness of consequences of hypohydration • Fear of weight gain (energy containing drinks) • Fear of needing to urinate during competition

2.5.2 Assessing Hydration status

There is no single method of measuring hydration status in athletes. There are, however, some relatively straightforward processes which allow researchers to measure an athlete's hydration status using certain biomarkers. This can be essential to improving performance and attenuating a physical decline.

Urine concentration & volume

Urine is a solution consisting of water and various other properties. Urine markers for dehydration include, but are not limited to urine specific gravity (U_{SG}), urine osmolality (U_{Osm}), urine volume and urine colour (U_{col}). A relative increase in each parameter over a certain value can indicate dehydration. U_{SG} analysis using a refractometer allows a researcher to assess the density of a urine sample relative to water. All three biomarker samples can be obtained relatively simply through excreting urine with no discomfort to the athlete.

Body mass & body water percentage

Daily body mass (BM) variation is a recognised method of estimating body water loss due to dehydration (Armstrong et al., 1994). Change in BM can show either an increase or decrease in hydration level through body water loss or gain. An acute loss of ≥ 2% in BM indicates that dehydration has occurred (Cheuvront, Ely, Kenefick, & Sawka, 2010). Anything less than this should not be considered atypical as BM fluctuations of 1-2% do not have a reliable association with total body water (TBW) loss, and is therefore not an indicator of dehydration (Cheuvront et al., 2013). BM losses of ≥ 2% have shown to impair endurance performance caused by a decline in physiological capacity (Edwards et al., 2007; Gonzalez-Alonso et al., 1998). During prolonged exercise, BM often decreases through this reduction in TBW due to an increased rate of sweating and insufficient fluid replacement. It is a useful, inexpensive measurement but can be confounded by changes in body composition when exercising over long periods of time (Kenefick, Cheuvront, Leon, & O'Brien, 2012).

Plasma volume & osmolality

Blood concentration is frequently used as a marker of hydration status (Costill & Sparks, 1973; Horstman & Horvath, 1972). Osmolality of the serum, or plasma osmolality (P_{Osm}) is widely considered to be a gold standard method of assessing hydration status (Cheuvront & Sawka, 2005). The marker directly reflects sodium levels in the blood which rise as sweating increases. Despite being a commonly used method of determining hydration status, P_{Osm} is not used for estimating fluid requirements. This is because P_{Osm} values are controlled between ~277 - 281 $mOsm{\cdot}kg^{-1}$ along various fluid intakes (Armstrong, 2007). The blood plasma volume (PV) is often calculated through using recorded haemoglobin (Hb) or haematocrit/packed cell volume values. An acute increase in the ratio of Hb in the blood reflects a decrease in PV when there is insufficient fluid intake (Mairbäurl, 2007). Nose, Mack, Shi, and Nadel (1988) reported an increase in PV alongside the increase in fluid intake after subjects were dehydrated by 2.3% of their respective body weights. Assessing hydration status can provide important information to athletes helping improve performance and attenuate the increased physiological strain caused by dehydration (Casa et al., 2000). Being aware of the benefits of maintaining a euhydrated state can prevent the potential risks of dehydration.

2.5.3 Hydration strategies

Water and electrolyte balance are essential for homeostatic function and for general health benefits (Sawka, Montain, & Latzka, 1996). It is recommended that athletes consume fluid regularly before exercising and then periodically during exercise to combat fluid lost through sweat (Sawka et al., 2007). However, when dehydrated, it is recommended that exercising males should consume water in excess beyond the amount to replace what has been lost in order to reduce physiological strain. HR, rectal temperature and P_{Osm} all increased when dehydrated (-3.9% BM) athletes consume more water than lost through sweating (Armstrong et al., 1997). Post-exercise rehydration is dependent on the hydration status of the athlete by the end of exercise.

Pre-performance

It is necessary for athletes to hydrate prior to exercise as in many team sports there is minimal opportunity to hydrate during match play. Despite this, it is not uncommon for soccer players to be dehydrated prior to exercise. A study from (Da Silva et al., 2012) reported that through urine analysis, 10 of 15 adolescent Brazilian players were dehydrated before competing (USG ≥ 1.020). There were similar findings in an investigation by Arnaoutis et al. (2013) involving 107 young male soccer players during a training camp. Approximately 90% of these soccer players began the training camp in a dehydrated state, with ad-libitum drinking not preventing any further dehydration in those who were already in a dehydrated state. With a moderate relationship observed between high intensity running (speed ≥19.8 $km \cdot h^{-1}$) in elite players and elite standard referees when performing (Weston., Drust., & Gregson., 2011), there is likely to be a similar risk placed on referees. Education about the importance of fluid intake is necessary for athletes to reduce the risk of dehydration in all conditions.

Hydration during performance

As the aforementioned studies suggest, dehydration leads to a decline in physical performance and increased physiological stress in the team sport athlete (Sawka et al., 2007). The substantial physiological stress placed on athletes is accentuated when the athlete is dehydrated (Davis et al., 2015; Horswill, 1998). Since the increase of international tournaments being hosted in hot climates (Brazil

2014 & Qatar 2020), FIFA officials have the choice to implement a drinks break period of 90 seconds after 30 minutes of match play. However, if there is a continued period of strenuous exercise without rehydration there can be extremely harmful health consequences (Casa, 1999; Sawka et al., 2007). Da Silva and Fernandez (2003) assessed dehydration in six referees and six assistant referees (linesmen) during a 90-minute soccer matches in one of Brazil's national leagues. The referees were allowed to rehydrate during the half-time break with water. Referees experienced a moderate level of dehydration (2% pre vs post decline in BM), with assistant referees only showing a non-significant dehydration of 1% of their BM. Furthermore, referee's water intake at the half-time break only replaced a quarter of fluids lost throughout the match.

The effects of different types of fluid (i.e. various sodium and carbohydrate concentrations) and hydration status during exercise has been previously researched (Baker & Jeukendrup, 2014; Maughan & Leiper, 1995). However, assessing hydration and performance measures when exercising under two specific drinking strategies (Ad-libitum vs restricted fluid intake) has been less comprehensively studied (Cian, Barraud, Melin, & Raphel, 2001; Nose et al., 1988; Rico-Sanz et al., 1996). There are potential health benefits, for both players and referees, in adopting a strategy for fluid consumption when exercising for a prolonged period of time (Coyle, 2004). The necessity of a structured approach is increased when unacclimated athletes perform in a thermal environment, due to an increased fluid loss (Shapiro, Pandolf, & Goldman, 1982); therefore, fluid intake requirements should be met in order to reduce the risk of complications when exercise occurs (Von Duvillard, Braun, Markofski, Beneke, & Leithäuser, 2004). It is recommended that fluid intake amounts to 500-2 $L{\cdot}h^{-1}$ depending on the duration and intensity of the competition and how acclimatised an athlete is to the competition environment (Lanham-New, Stear, Shirreffs, & Collins, 2011). Temperate conditions require a daily fluid intake of between 2-4 L, depending on the aforementioned criteria. These requirements can double in hot climates due to the increased sweating rate (Sawka & Montain, 2000). However, as previously mentioned, it is unlikely these demands will be fulfilled due to the limited time made available to consume fluids during a competitive soccer match. Within team sports there are varied opportunities for players to consume fluid (Burke, 2007).

Gastric Emptying

As previously mentioned, there are reported benefits from pre-exercise fluid intake. However, when amounts beyond requirements are consumed, much of the fluid will be expelled as urine. The body is able to regulate the balance of fluid, but in some cases it can lead to a state of hyponatraemia (low sodium blood levels) (Burke & Deakin, 2000). The gastro-intestinal tract plays a pivotal role in the regulation of fluid balance and the rate of emptying can be affected by various factors such as fluid osmolality, beverage temperature, fluid volume, exercise and body temperature. The increase in thermal strain has a detrimental effect on the rate of gastric emptying (Gisolf, 1993). Neufer, Young, and Sawka (1989) discovered an inverse correlation in the rate of gastric emptying with core temperature in subjects that exercised in 45ºC and subjects that begun exercise hypohydrated in 35ºC. Early work from Hunt and Spurrell (1951) highlighted that gastric emptying was increased with the ingestion of fluid, suggesting that continuously taking on fluids increases the quantity of fluid in the stomach. Later research by Costill and Saltin (1974) yielded similar results, however the researchers argued that gastric volume was not the cause of the increased emptying rate. They proposed that increasing fluid intake increased pressure within the stomach causing an improved rate of gastric emptying, up to a limit of ~600 mL; therefore, stating that increased fluid intake can improve gastric emptying of fluids to a certain extent, at which point, subjects could begin to experience gastro-intestinal discomfort.

2.6 Heat stress and performance:

2.6.1 Temperatures at major tournaments

As previously mentioned, there are an increased number of major tournaments being hosted in equatorial or middle eastern nations. Traditionally major international soccer tournaments have been played in the summer months (June & July) during the off season of domestic football. All previous European Football Championships have unsurprisingly been hosted in European countries with the tournaments also being played in June and July. With daytime temperatures of > 30ºC and relative humidity > 70% in some major tournament locations, far more attention is being focussed on the effects heat stress can have on athlete’s performance levels and health (Bergeron et al., 2012).

2.6.2 Physiological changes during exercise in heat

There are several health implications of prolonged exercise in the heat, beginning with smaller complications like heat stress that eventually lead to heat injury or illness, heat stroke, syncope and organ dysfunction (Kilbourne, 1997).

Background of Thermoregulation

Humans are homoeothermic; heat is gained through a combination of factors including radiative heat and metabolic processes through exercise. When heat gain outweighs heat loss, there is a subsequent increase in thermal load, causing an increase in body temperature. The hypothalamus contains the body's thermoregulatory centre, where information is sent via central thermoreceptors in the brain, central nervous system and internal organs. If skin temperature changes, information is sent from the peripheral thermoreceptors causing the thermoregulatory system to increase blood flow to the peripheries through vasodilation to reduce core temperature. A rise in core temperature has been reported to have a very strong relationship with an increase of HR ($r^2 = 0.98$, $P = 0.001$; Gonzalez-Alonso et al. (1999)) showing there is reason to believe prolonged heat stress can lead to a cardiovascular decline during exercise.

Cardiovascular drift

Cardiovascular drift (CV drift) is a time-dependent increase in CV responses during moderate intensity endurance exercise when no change in intensity has occurred (Coyle & Gonzalez-Alonso, 2001). It is suggested that this phenomenon is a result of an increase in cutaneous vascular resistance when subjects are dehydrated (Gonzalez-Alonso, Mora-Rodriguez, Below, & Coyle, 1995), consequentially reducing SV and therefore cardiac output. Another relevant study proposed that the decline in cardiovascular capacity is linked to the increase in core temperature in euhydrated subjects. (Fritzsche, Switzer, Hodgkinson, & Coyle, 1999). This suggests that both dehydration and hyperthermia are factors that increase HR and lower SV, subsequently leading to decline in endurance performance (Hoff, 2005).

2.6.3 Heat stress and performance

Despite the aforementioned research on hyperthermia and dehydration, there is still no definitive conclusion on the effects of heat stress on performance with several factors affecting performance markers. (Drust, Rasmussen, Mohr, Nielsen, & Nybo, 2005) investigated the effect of an intermittent heat stress protocol on repeated sprint ability in cyclists. Despite an increase in muscle temperature, normally resulting in an increase in muscle activation and power output, there was a performance decline in sprints towards the end of the protocol, when athletes exercised in hot conditions (40ºC), or thermoneutral conditions (20ºC) (558.0 $\pm$ 146.9 W vs 617.5 $\pm$ 122.6 W; $P < 0.05$). Similar results were found in earlier research by Ball, Burrows, and Sargeant (1999), where fatigue was accelerated in cyclists during a repeated sprint cycle exercise protocol. It is believed that this phenomenon was caused through a concomitant increase in core temperature. This is likely to occur, most frequently, when athletes are competing or training in hot environments (G. Morris, Nevill, Lakomy, Nicholas, & Williams, 1998; Gonzalez-Alonso et al., 1999).

2.6.4 Subjective measures during exercise in heat

It has been previously reported that rate of perceived exertion (RPE) (Borg, 1982) is a valid method of measuring training load in soccer players (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). Therefore, it would be a useful measure in gaining an understanding of how athletes perceive their physical load when under heat stress. Furthermore, the recording of subjective thermal measures is important in understanding a subject’s perception of thermal load. It is understood that both core and skin temperature influence thermal behaviour responses during exercise (Schlader, Simmons, Stannard, & Mündel, 2011). Morante and Brotherhood (2008) observed thermoregulatory responses and workload in 25 tennis players playing matches in a range of ambient temperatures (14.5 to 38.4ºC; Mean (SD) = 25 $\pm$ 5.4 ºC). The researchers also recorded the following subjective ratings: RPE, thermal comfort & sweatiness. Thermal comfort was reported to have a moderate correlation with measured skin temperature ($r^2 = 0.41$; $P < 0.0001$) as opposed to a weak positive correlation with rectal temperature ($r^2 = 0.05$; $P < 0.03$). These skin temperature data support earlier research on thermal comfort (Chatonnet & Cabanac, 1965) and more recent research on tennis players where thermal comfort, thermal sensation and perceived exertion were all elevated in ‘hot’ conditions in comparison to a ‘cool’ environment (Périard et al., 2014).

2.7 Summary

In soccer, it is understood that the referee plays an incredibly important part of the game. It’s imperative that he or she is in their peak possible condition throughout the duration of match play. With performance declining towards the latter stages of matches, it is even more essential that the referee can be alert and aware, but also physically capable to keep up with the direction of play. It is evident that dehydration is accelerated in thermal conditions, which leads to an acceleration in physiological performance decline. Being able to adequately rehydrate to meet fluid requirements can attenuate this performance decline, and potentially enhance the performance of referees who begin the game in a dehydrated state. Therefore, with regards to the current study, it is important that the subjects are performing at the same physical capacity to limit the variation in responses. The present study uses Abt and Lovell (2009) method of obtaining speed thresholds. This process has previously been reported to be a more sensitive indicator than aerobic capacity (VO_{2max}) in identifying training status (Edwards, Clark, & Macfadyen, 2003; Rampinini et al., 2007).

Chapter 3

Methods

3.1 Participants

Fourteen apparently healthy male athletes participated in the study.

Table 4 The mean (±SD) participant characteristics.

	Mean (±SD)
Age	21 ± 2.1
Height (cm)	180.7 ± 4.1
Body Mass (kg)	77.4 ± 6.6
VO_2max (ml•min•kg^{-1})	54.5 ± 5.8

3.2 Procedure

The procedure was approved by the research ethics committee of The University of Hull. Participants were briefed on what was required of them in order to ensure that they understood and were fully comfortable with the testing procedure. This was checked through participants being required to fill out a departmental informed consent form (Appendices A). It was also required that all participants completed the departmental pre-exercise medical questionnaire (Appendices B). These forms were checked to ensure that the participant had no existing medical conditions that may affect the testing procedures. If a participant met any part of the exclusion criteria, he would be removed from the study. Participants were informed that they were free to withdraw from the study at any time of the study and could do so without giving reason. All testing procedures were carried out within the environmental chamber at The University of Hull. Participants were informed that they would be kept anonymous throughout and any data would be kept confidential.

In total, participants were required for testing on three separate occasions. This consisted of an individualisation session, and two soccer simulations under two different conditions (following a randomized crossover design). All participants were required to have fasted for two hours prior to exercise. Participants were required to wear the same clothing in all three trials to avoid body temperature changes through clothing insulation.

3.2.1 Individualisation

3.2.2 Match activity thresholds – Arbitrary vs Individualised

Recording match activity data has been practiced more frequently in recent years. The creation of arbitrary activity thresholds is useful for understanding training load during soccer performance. It also provides a basis for creating a soccer specific simulation to try to mimic field performance in a laboratory setting. Abt and Lovell (2009) investigated the use of an individualised high-intensity speed threshold using VT_2 to assess the distance covered at high-intensity during match play. VT_2 was used as an indicator of high intensity exercise due to the player's inability to maintain exercise at an intensity above this threshold. The researchers concluded that the players' speeds when reaching VT_2 differed substantially from the absolute threshold used. Additionally, the high-intensity speeds reported were lower than the arbitrary units for high-intensity running obtained by ProZone. The importance of individualising speed thresholds has previously been overlooked, with arbitrary thresholds being implemented despite evidence that the speed at which each player reaches high intensity can differ (Abt & Lovell, 2009). If arbitrary thresholds are used in exercise prescription or to simulate soccer performance, this can result in an imbalanced physiological load placed on players or referees. As previously mentioned, the demands of a soccer match lead to increased concentrations of blood lactate in referees towards the end of match-play.

A study by Castagna, Abt, and D'Ottavio (2002) observed the relationship between selected blood lactate thresholds and match activities in elite soccer referees. Despite, there being a moderate correlation ($r = 0.73$, $p < 0.05$) between the running velocity at a blood concentration of 4 $mmol \cdot L^{-1}$, a stronger relationship had been reported previously between match performance and VO_{2max} (Bangsbo, 1994).

The first visit consisted of a ramped test to exhaustion (Lovell & Abt, 2013) on the motorised treadmill (H/P/Cosmos, Nussdorf-Traunstein, Germany). Before the test began, participants' height was measured using the Holtian Stadiometer (Holtian Ltd, Crymych, Dyfed) and BM was measured using the SECA Digital Scale (Vogel & Halke, Hamburg, Germany). Heart rate (resting and during exercise) was also measured using the recordable heart rate watch and chest strap (Polar Electro, OY, Finland). Participants were also fitted with facemask (Cortex Biophysic, Leipzig, Germany) connected to a Cortex metalyzer (Cortex Biophysic, Leipzig, Germany) to measure expired air. Before the test began, the treadmill was set to a gradient of 2%, and remained inclined for the entirety of the session. The test began at a speed of 7 $km \cdot h^{-1}$ and remained at this intensity for 3 minutes, at which point the speed was increased by 0.2 $km \cdot h^{-1}$ every 12 seconds. Measurements of participant ventilatory threshold (VT_1), respiratory compensation point (VT_2) and maximal aerobic speed (MAS) were recorded throughout the test and were used to determine each players' individual intensities for the two thermal soccer simulations. VT_1 was determined using the point at which there was a rise in both the ventilatory equivalent for oxygen (VE•VO2) and partial pressure of oxygen ($P_{ET}O_2$) with no accompanying increase in the ventilatory equivalent for carbon dioxide ($VE \bullet VCO_2^{-1}$). The second ventilatory threshold was calculated using the point at which there was a sudden inflection in $VE \bullet VO2^{-1}$ and $VE \bullet VCO_2^{-1}$ along with a decrease in end-tidal partial pressure of carbon dioxide ($P_{ET}CO_2$) (Lucia et al. (2000); Abt & Lovell, (2009).

3.2.3 Environmental conditions

Participants were required to complete two soccer simulations in 30ºC & 45% RH. Ambient temperature during exercise was chosen through using archived temperature of venue locations during previous European Championships and FIFA World Cups dating as far back as the 2006 World Cup in Germany. The data were taken from Weather Underground (wunderground.com). Additionally, archived temperature data from the future locations of European Championships and FIFA World Cups was used to predict potential temperatures during these international competitions. The data provided by Weather Underground was recorded using BestForecast™ which creates and documents accurate weather forecasts from data recorded at airport weather stations, personal weather stations along with other weather stations that are run by various government organisations (Wunderground, 2003).

3.2.4 Soccer simulation

On arrival participants were asked to complete a medical questionnaire to ensure they were physically able to undergo the testing protocol. Nude BM and height were measured, and a urine sample was taken prior to the rectal probe being inserted. U_{Osm}, U_{SG} and urine colour were assessed using the provided urine sample. U_{Osm} was measured using an Osmometer (Model 3320, Advanced Instruments Inc, Massachusetts, USA). USG was assessed using a digital refractometer (PEN SW, ATAGO, Washington, USA), whilst urine colour was determined using a urine colour chart. Urine was also assessed at the end of the exercise protocol. Once the participant had returned with the urine sample, capillary blood samples were taken by finger prick method. Capillary blood samples were taken prior to exercise, at the 15 minute intervals, and at the end of the second 45 minute exercise bout. The capillary blood samples were used to measure haemoglobin and haematocrit levels. Haemoglobin was measured using a lancet (Genie lancet 1 X 1.5, BD Vacutainer, Systems, NJ, USA) filled with blood and analysed in the Hemocue haemoglobin analyser (Hemocue 201, Hemocue Ltd, Sheffield, UK). For Haemoglobin and Haematocrit values, blood was filled into a capillary tube (Hawksley haematocrit tube, Roche Diagnostics, Sussex, UK) and then placed in a centrifuge to be spun for 10 minutes (Hawksley Micro Haematocrit Centrifuge, Hawksley & Sons, Lancing, UK). The samples were then read using a tube reader (Hawksley reader, Hawksley & Sons, Lancing, UK) and recorded. A recordable heart rate watch and chest strap were used along with four skin thermistors attached to the chest (T_c), bicep (T_b), thigh (T_t) and gastrocnemius (T_c). Core (T_{rec}) temperature from the rectal probe and skin temperature (T_{sk}) were recorded using the Grant squirrel data logger (Squirrel 2020 series data logger, Grant Instruments, Cambridge, UK).

On entering the environmental chamber, participants completed a 5 minute warm up on the cycle ergometer (Wattbike Ltd, Nottingham, United Kingdom). The soccer simulations were conducted on the same motorised treadmill used during the individualisation process in the environmental chamber, and consisted of two 45 minute bouts of exercise, either side of a 15-minute half-time interval. Both halves were split into three identical 15-minute blocks with each 15 minute block split into 5 minute exercise bouts. For the present study, six intensities thresholds were used (Table 3) with 15 activity changes for each five minute block (excluding the 3rd and 6th five minute block which have 14 activity changes). At the end of each exercise bout, the participant would complete a six second maximal sprint on the cycle ergometer (Wattbike Ltd, Nottingham, United Kingdom). Peak power output (PPO) and mean power output (MPO) was recorded after each sprint. MPO was calculated as the average power out recorded on the cycle ergometer over the full 6-second sprint period. The power output was measured using a measurement System Strain Gauge, which measures the force applied through each pedal at 100 data samples per second.

Table 5. Speed, intensities and durations for each component of the soccer simulation trial.

Intensity	Mode	Duration (s)
Standing	Treadmill	45
Walking	Treadmill	75
VT_1	Treadmill	75
VT_2	Treadmill	45
MAS	Treadmill	30
Maximal Sprint	Cycle ergometer	6

Key: VT^1 = Ventilatory Threshdold, VT^2 = Respiratory Compensation Point, MAS = Maximal Aerobic Speed

Participants completed two soccer simulation under separate conditions. The dehydration trial (DE) required the athletes to complete the trial while only consuming 300 mL of water at the 15 minute interval. The fluid trial (FL) gave the athletes the option to consume water at any point from the start of exercise. This was achieved through the participant wearing a personal fluid delivery system (PFDS) (Camelbak Circuit, Camelbak Products Inc, Inc, Petaluma, CA, US). The PFDS bladder was filled with 1.2 L of cold (7ºC) water and weighed before exercise. The participant was then instructed to consume water through the mouthpiece whenever they had the desire to. The PFDS was removed during the 15 minute interval and the participant then consumed 300 mL of water after capillary blood samples were taken. The PFDS bladder was weighed before being emptied and weighed again once refilled with 1.2 L of cold water and then weighed for a final time after the second 45 minute exercise period. The selection of water was justified by the fact the study was assessing primarily fluid intake along with the effect fluid intake has on performance and thermoregulation. Therefore, it was easier to control and avoid variability in results caused by other metabolic factors.

HR, T_{rec}, T_c, T_b, T_t, T_g, RPE, thermal comfort (TC), thermal sensation (TS) (Appendices C) were recorded after the five minute warm up, before the 2nd half began and every five minutes during exercise.

3.3 Data analysis

PV% change was calculated using the Dill and Costill (1974) method.

Mean skin temperature (MST) and mean body temperature (MBT) were determined using the following calculations:

MST = $0.3\ T_c + 0.3\ T_b + 0.2\ T_t + 0.2\ T_g$ (Ramanathan, 1964)

MBT = $0.9\ T_{re} + 0.1$ MST (Sawka, Wenger, Young, & Pandolf, 1993)

The amount of water consumed in each 45 minute bout was calculated through the following process:

1st half = (pre exercise PFDS mass) - (45 minute PFDS mass)

2nd half = (pre 2nd half PFDS mass) - (90 minute PFDS mass)

Total sweat Loss was estimated through the following calculation:

Fluid Deficit (pre exercise BM - post BM (L)) + volume of fluid consumed during exercise - urine loss (Burke, 2007)

Sweat rate (L/h) was estimated through the following calculation:

Total sweat loss / Total duration of exercise (Burke, 2007)

3.4 Statistical Analysis

The mean and standard deviation (SD) were used as statistical analysis for subject characteristics (Table 2). Mean and SD were also calculated for performance variables, hydration markers and temperature markers. The primary statistical analysis procedure was applied in a pre-post crossover spreadsheet for the purpose of creating between trial inferential statistics (Hopkins, 2006). Inferential analysis calculated effect sizes and confidence intervals for the means of variables in the two compared trials in order to show the size of the fluid intakes effect and contextualise it with the rest of the population. All data are reported as the mean difference with 90% confidence intervals (90% CI) and Cohen's *d* effect size. Effect sizes are classified according to the following criteria: 0-0.19 trivial; 0.2-0.59 small; 0.6-1.19 moderate; 1.2-1.99 large; >= 2 very large. If the confidence interval crossed zero then the effect was deemed to be unclear. A post-cross over spreadsheet was used for the purpose of calculating inferential statistics to assess the effect of each half on fluid intake, but also on the effect of fluid intake on variables in each half (Hopkins, 2006).

Chapter 4

Results

4.1 Fluid intake

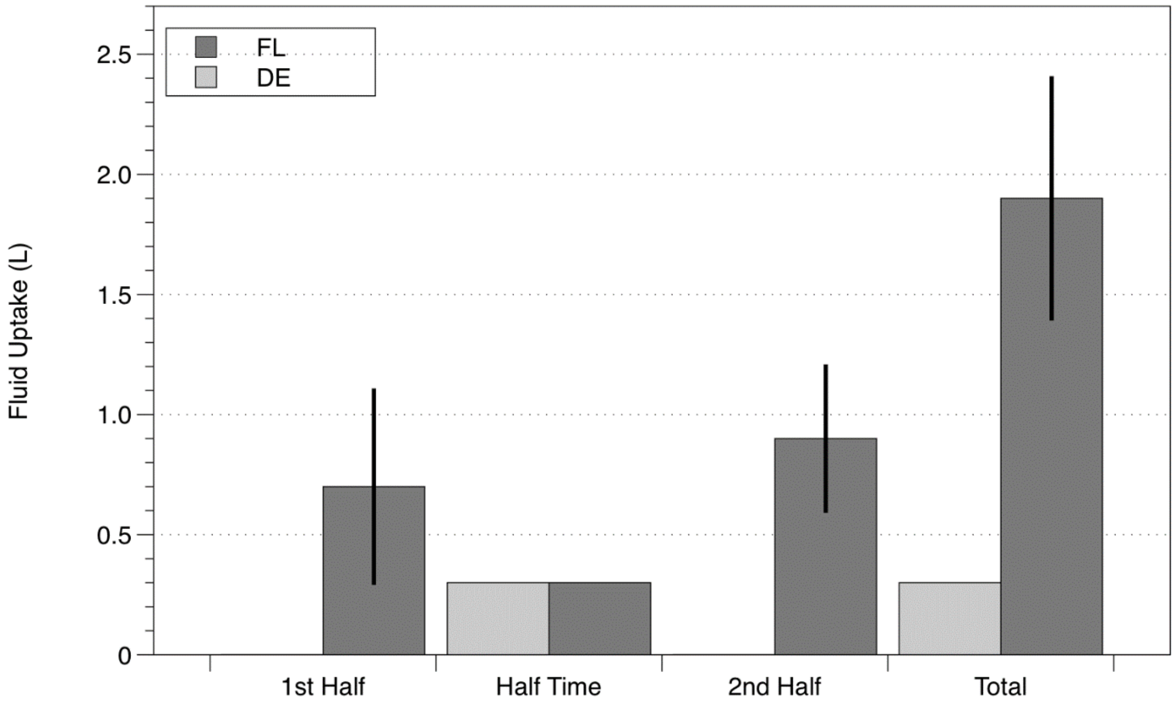

Figure 1. The mean (SD) fluid intake for the first half, half time break, 2nd half and the total over the full duration of the fluid trial (FL) and dehydration trial (DE).

In relation to fluid consumption, Figure 1 highlights that subjects consumed more fluid in both halves (1st half = 0.7 ± 0.4L, 2nd half = 0.9 ± 0.3L) when having the option to drink compared to being restricted to just 0.3L at half time in the DE trial. Figure 1 also identifies an increase in fluid intake in the 2nd half of the fluid trial compared to the first half. Inferential analysis for fluid intake between trials is presented in Figure 2.

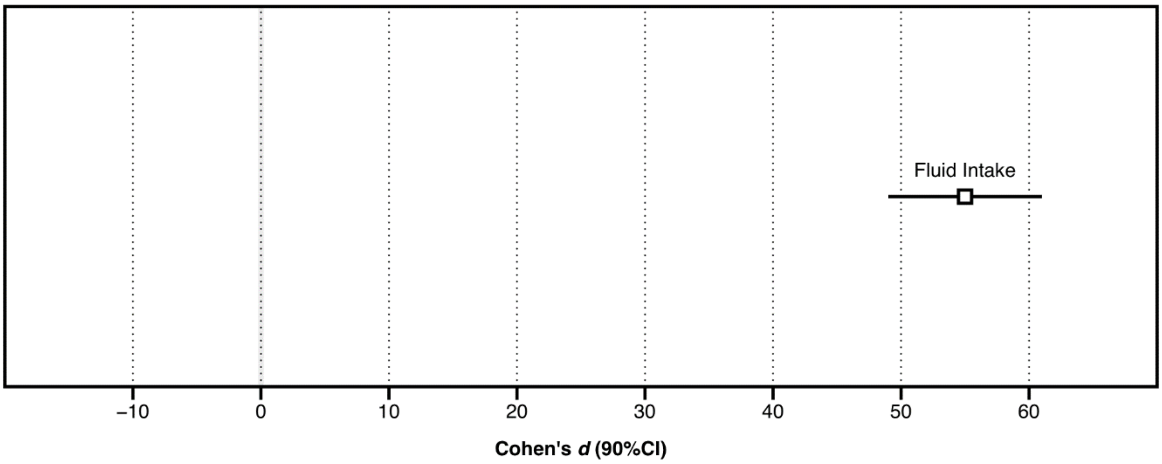

Figure 2. The mean difference as a Cohen's effect size (ES) (± 90% CI) for fluid intake between the dehydration and Fluid trials.

Regarding fluid intake, Figure 2 highlights that the conditions of the fluid trial have a very large effect on the amount of fluid consumed by subjects throughout the trial (ES = 55 ± 6).

4.2 Performance Variables

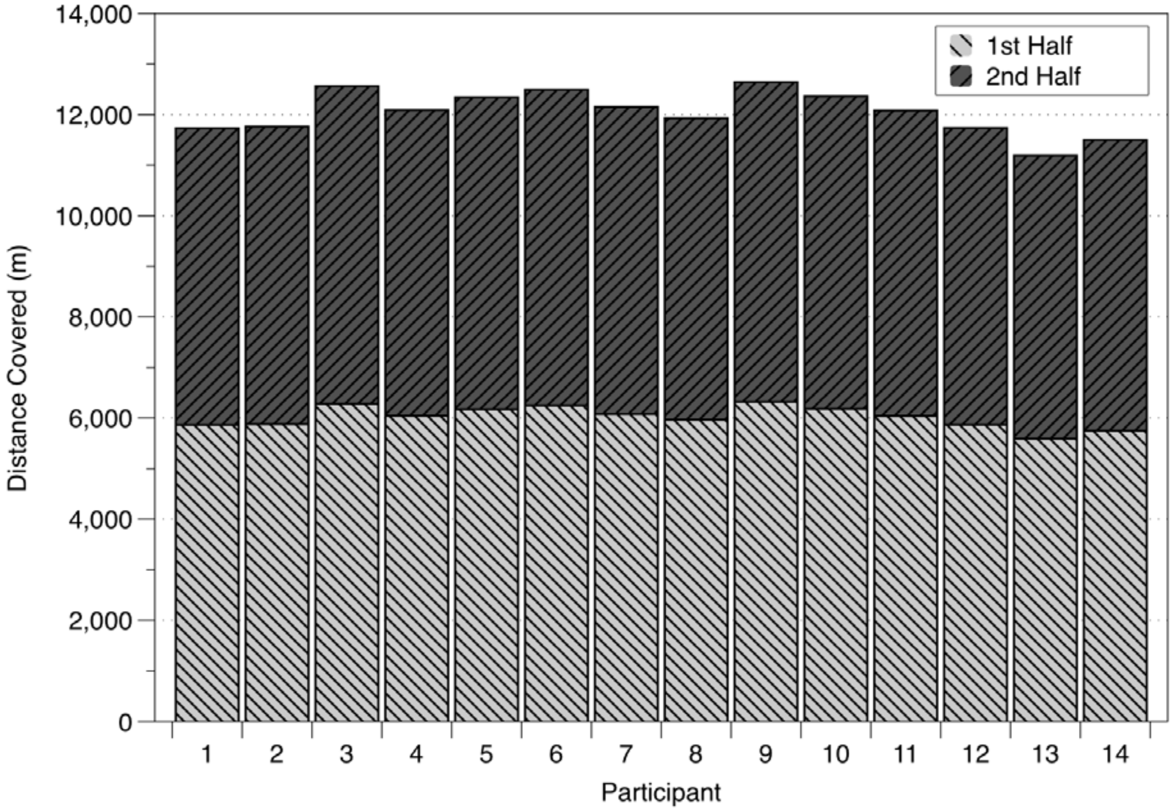

Figure 3. The distance covered for the 1st, 2nd half and total duration of the soccer simulation. The distance covered was equal in both halves and was the same in both trials. The mean distance covered for each half was 6020 ± 212 m. The mean distance covered over the full trial was 12040 ± 424 m.

In relation to distance covered, Figure 3 displays that all participants covered a total distance of ~12 km. 1st half and 2nd half distances covered were equal for each participant. Distance covered was the same in both dehydration and fluid trials.

4.2.2 Peak Power Output

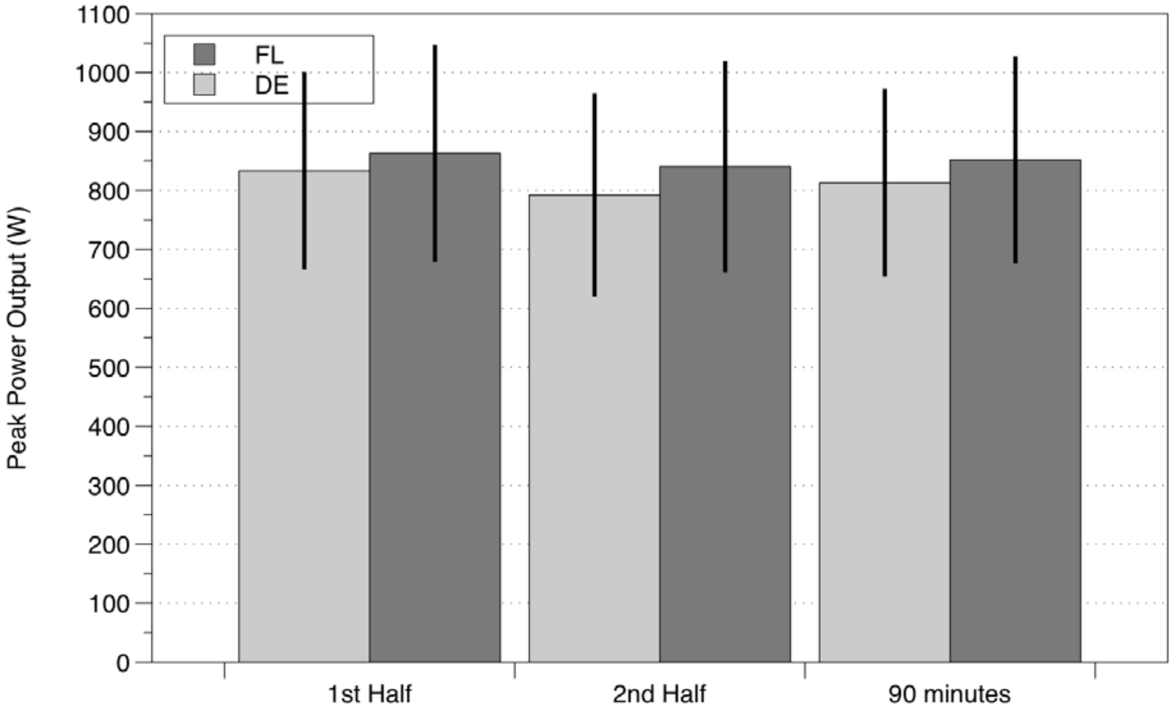

Figure 4. The mean (SD) peak power output for the Dehydration and Fluid trials during the 1st and 2nd half and over the 90-minute treadmill protocol. DE = Dehydration trial, FL = Fluid trial.

Peak power output was 833.5 ± 163.5W vs 862.9 ± 180.3W for DE versus FL respectively in the 1st half and was minimally changed at 792.4 ± 169.1W vs 840.5 ± 172.3W for DE versus FL respectively in the 2nd half. Inferential analysis for performance outcomes between trials is presented in Figure 6.

4.2.3 Mean Power Output

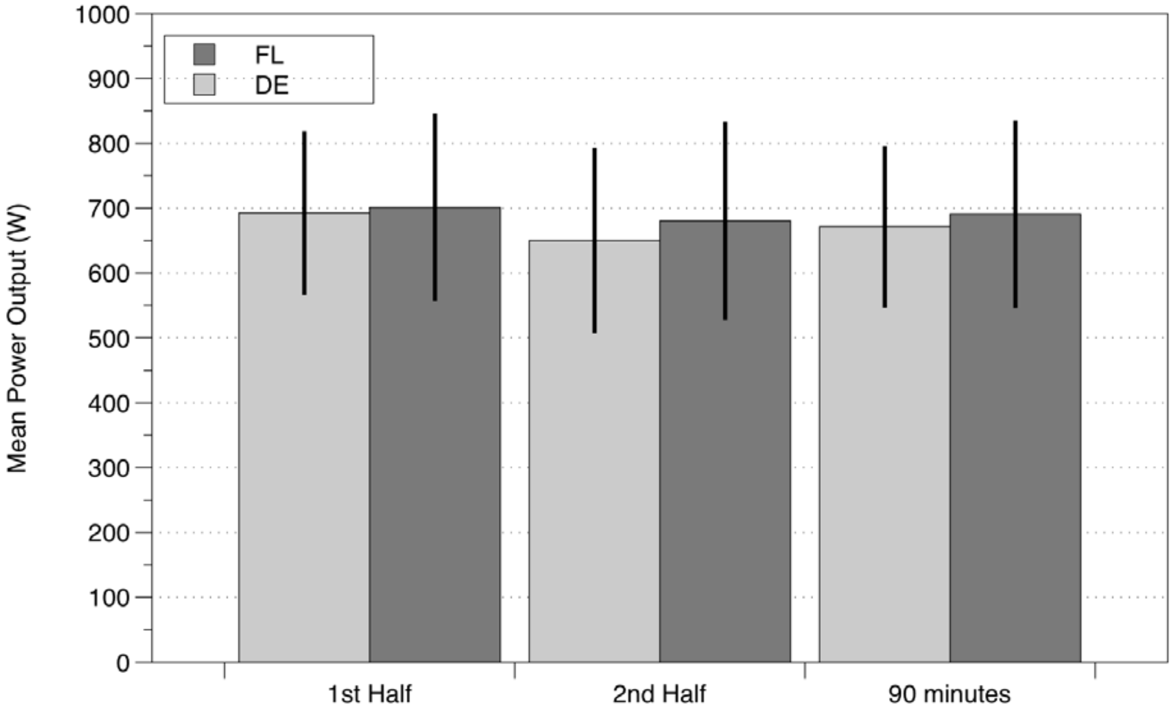

Figure 5. The mean (SD) power output for the Dehydration and Fluid trials during the 1st and 2nd half and 90-minute treadmill protocol. DE = Dehydration trial, FL = Fluid trial.

Mean power output was 692.6 ± 122.8W vs 701.2 ± 169.1W for DE versus FL respectively in the 1st half and was little changed at 650.1 ± 121.2W vs 680.5 ± 149.4W for DE versus FL respectively in the 2nd half. Inferential analysis for performance outcomes between trials is presented in Figure 7.

4.2.4 Heart Rate

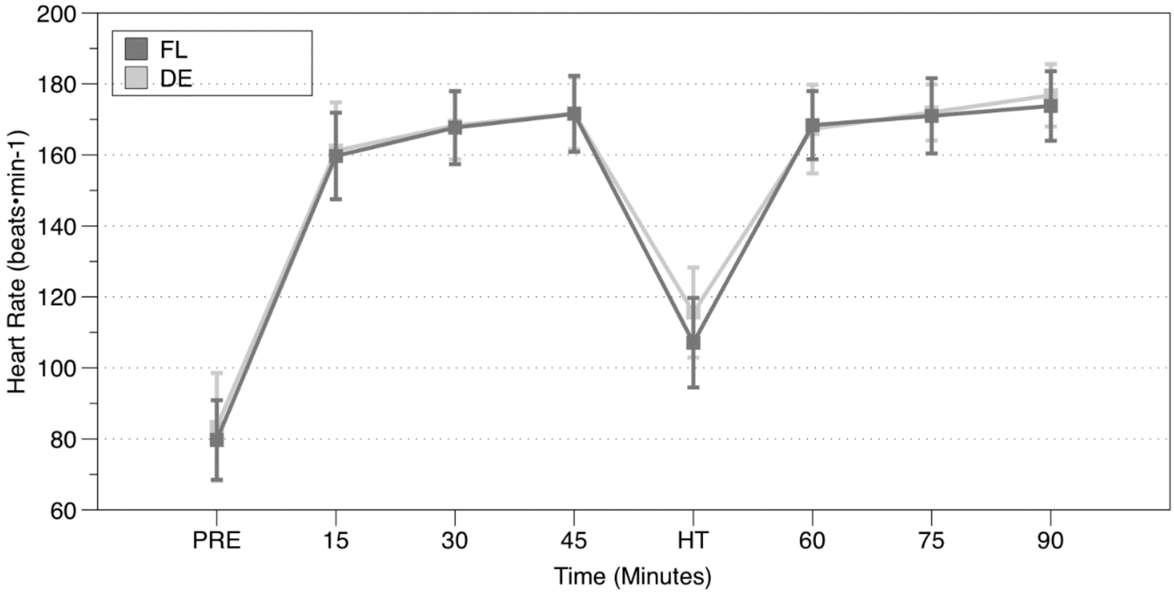

Figure 6. The mean (SD) heart rate (beats·min^{-1}) before exercise began, and then at 15 minute intervals during the dehydration and fluid trials. DE = Dehydration, FL = Fluid. HT = End of half time.

Heart rate experienced almost no change at 167.9 ± 8.8 beats·min^{-1} vs 166.3 ± 10.7 beats·min^{-1} for DE versus FL respectively in the 1st half and changed minutely at 172.86 ± 6.7 beats·min^{-1} vs 170.8 ± 9.5 beats·min^{-1} for DE versus FL respectively in the 2nd half. Inferential analysis for performance outcomes between trials is presented in Figure 7.

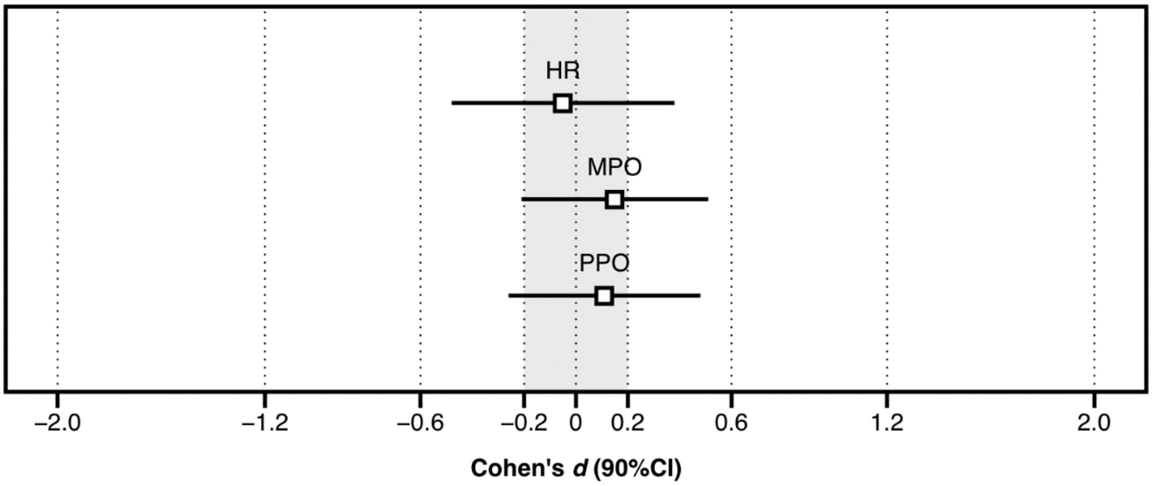

Figure 7. The mean difference as a Cohen's effect size (± 90% CI) for performance and physiological variables between the dehydration and fluid trials. HR = Heart rate, MPO = Mean Power Output, PPO = Peak Power Output. FL = Fluid trial, DE = Dehydration trial.

Regarding performance outcomes, Figure 7 highlights that ad-libitum water supplementation likely has no effect on heart rate (ES = -0.07 ± 0.47) and peak power output (ES = 0.13 ± 0.37). However, it displays that it could possibly have a small positive effect on mean power output over the full trial (ES = 0.15 ± 0.36).

4.3 Temperature measures

Table 6. Temperature measures for Rectal temperature, mean (SD) body temperature and mean skin temperature in both dehydration and fluid trials.

	T^{rec} (°C)		MBT (°C)		MST (°C)	
Time (min)	**DE (SD)**	**FL (SD)**	**DE (SD)**	**FL (SD)**	**DE (SD)**	**FL (SD)**
Pre	37.00 (0.46)	37.02 (0.21)	36.50 (0.43)	36.55 (0.22)	32.01 (0.68)	32.27 (0.56)
15	37.36 (0.41)	37.38 (0.19)	37.01 (0.38)	37.01 (0.18)	33.62 (0.37)	33.79 (0.32)
30	38.12 (0.28)	38.01 (0.32)	37.73 (0.27)	37.63 (0.27)	34.02 (0.39)	34.32 (0.41)
45	38.66 (0.21)	38.64 (0.17)	38.24 (0.27)	38.19 (0.15)	34.23 (0.53)	34.26 (0.59)
HT	38.28 (0.13)	38.27 (0.49)	37.85 (0.22)	37.81 (0.45)	34.02 (0.78)	33.64 (0.58)
60	38.34 (0.18)	38.32 (0.30)	37.89 (0.14)	37.87 (0.26)	33.78 (0.54)	33.79 (0.66)
75	38.67 (0.26)	38.59 (0.27)	38.23 (0.20)	38.18 (0.28)	34.30 (0.60)	34.32 (0.78)
90	38.94 (0.18)	38.90 (0.28)	38.51 (0.20)	38.48 (0.27)	34.59 (0.76)	34.71 (0.78)

Key: T^{rec} = Rectal Temperature, MBT = Mean Body Temperature, MST = Mean Skin Temperature
DE = Dehydration trial, FL = Fluid trial

Table 6 shows the mean (SD) rectal temperature, body temperature and skin temperature across all participants in both conditions. The data is displayed in 15 minute intervals throughout the full protocol. The data in table 6 shows a linear increase during exercise with a decrease in temperature during the half-time interval. Inferential analysis for performance outcomes between trials is presented in Figure 8.

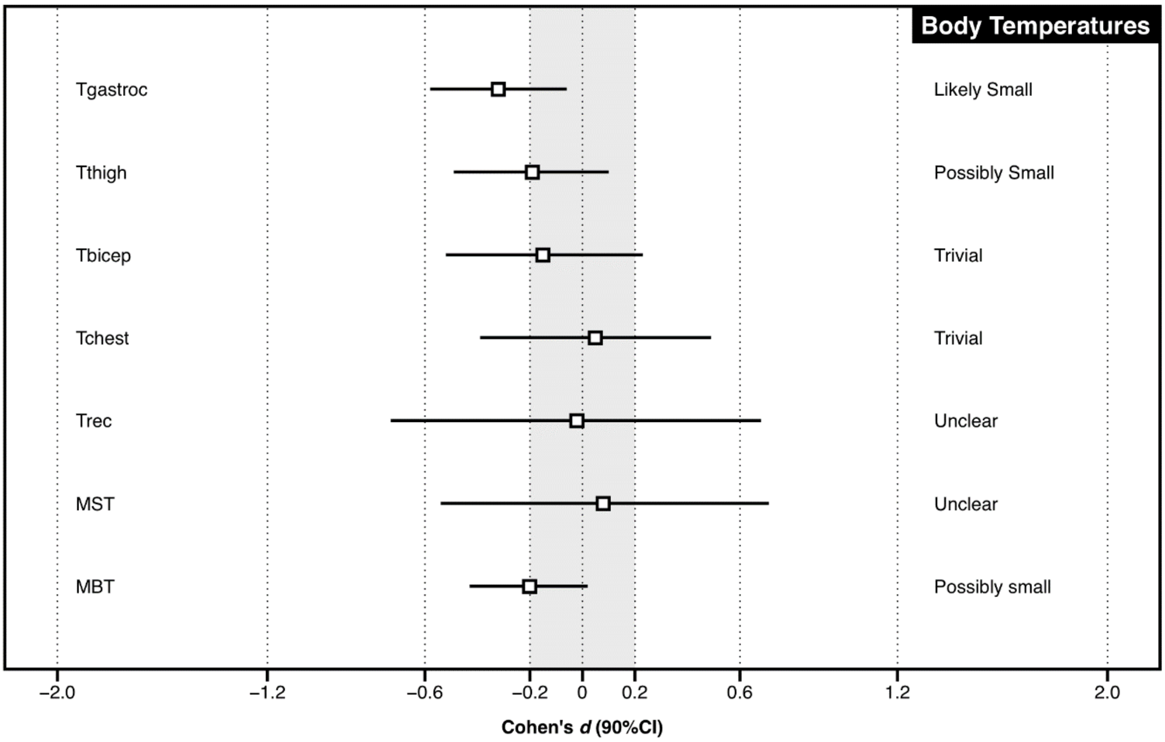

Figure 8. The mean difference as a Cohen's *d* effect size (± 90% CI) for body temperature response variables between the dehydration and fluid trials. FL = Fluid trial, DE = Dehydration trial.

Regarding body temperature responses, Figure 8 highlights that ad-libitum water supplementation had a small negative effect in gastrocnemius temperature (ES = -0.32 ± 0.26). It also identifies that ad-libitum water supplementation can possibly have a small negative effect on mean body temperature (ES = -0.32 ± 0.26) and thigh temperature (ES = -0.2 ± 0.22).

4.4 Hydration Markers

4.4.1 Body Mass

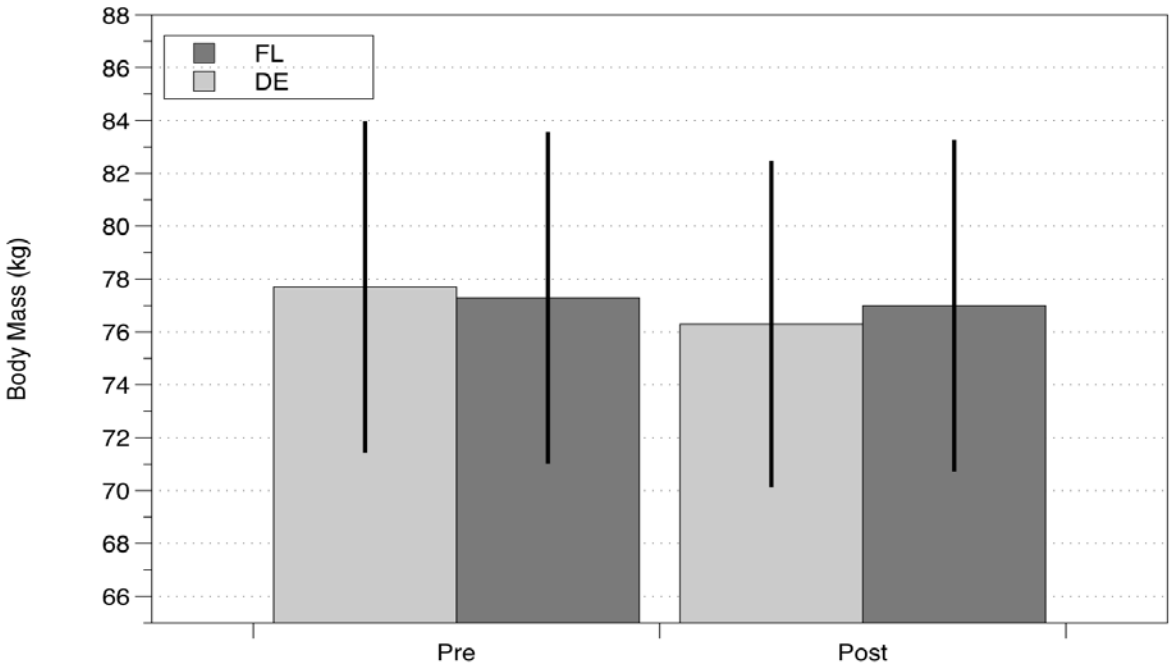

Figure 9. The mean (SD) pre and post body mass values in kg for both Fluid and Dehydration trials. FL = Fluid, DE = Dehydration.

Body mass decreased from 77.7 ± 6.2kg vs 76.3 ± 6.1kg for pre vs post for DE and decreased minimally from 77.3 ± 6.2kg vs 77 ± 6.2kg for pre vs post for FL respectively. Figure 9 highlights that participants' body mass decreased more when restricted to drinking solely at half time. Ad-libitum water supplementation throughout the full match maintained body mass in subjects. Inferential analysis for the pre and post body mass between trials is presented in Figure 15.

4.4.2 Urine Osmolality

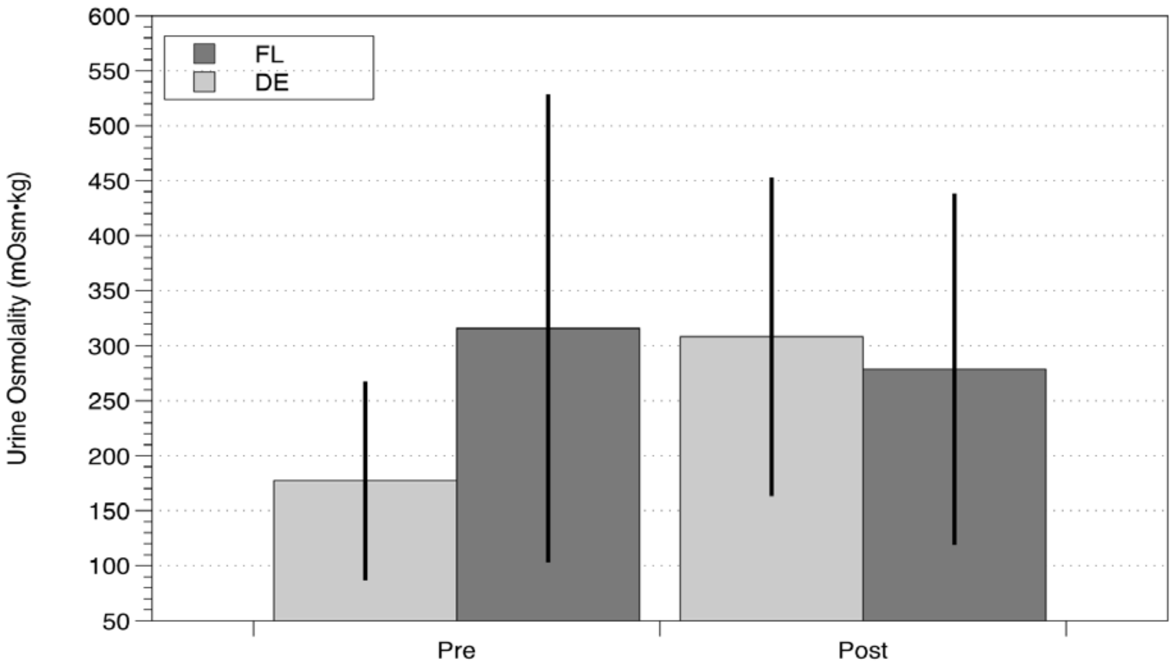

Figure 10. The mean (SD) pre and post urine osmolality in mOsm•kg^{-1} in for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid.

Urine osmolality increased from 177.1 ± 88.8 mOsm•kg^{-1} vs 308.2 ± 143.2 mOsm•kg^{-1} when comparing pre vs post for DE and decreased from 315.8 ± 210.9 mOsm•kg^{-1} vs 278.6 ± 158.1 mOsm•kg^{-1} when comparing pre vs post for FL respectively. Figure 10 displays that ad-libitum fluid supplementation led to a decrease in urine osmolality. Water intake solely at the half time interval didn't attenuate the decrease in hydration status but improved hydration status when fluid was consumed throughout the trial. Inferential analysis for pre and post urine osmolality between trials is presented in Figure 15.

4.4.3 Urine Specific Gravity

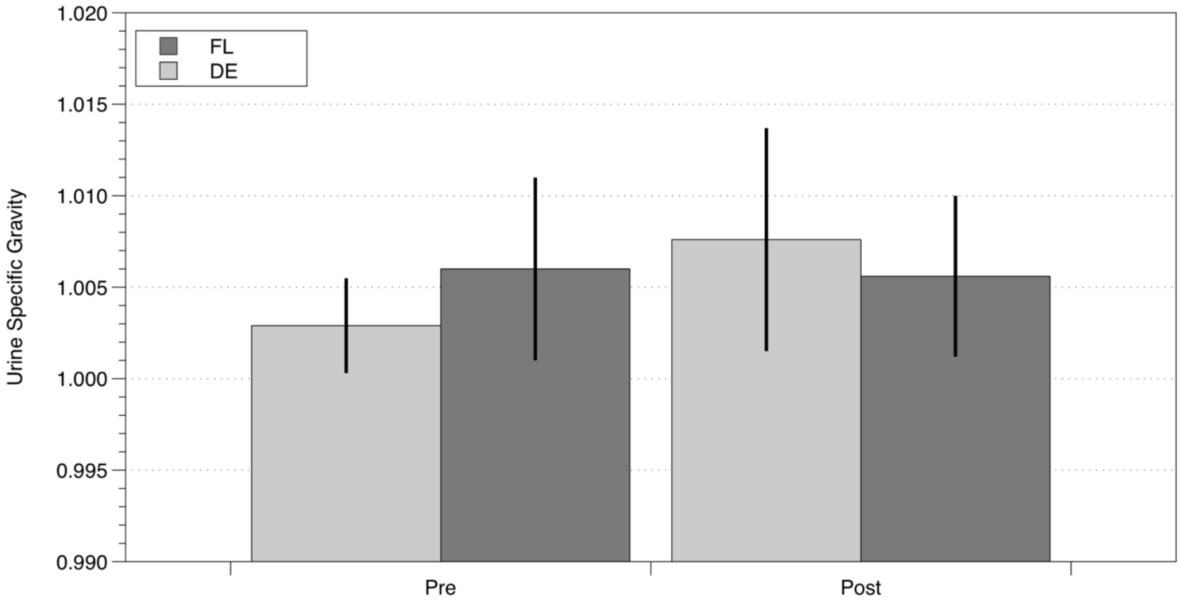

Figure 11. The mean (SD) pre and post urine specific gravity in for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid.

Urine specific gravity increased from 1.0029 ± 0.0026 vs 1.0077 ± 0.0060 when comparing pre vs post for DE and increased very slightly from 1.0060 ± 0.0050 vs 1.0062 ± 0.0047 when comparing pre vs post for FL respectively.

Figure 11 highlights that ad-libitum fluid supplementation maintained urine specific gravity when comparing pre to post-test measures. Water intake solely at half-time led to a decrease in hydration status in subjects when comparing pre to post. Inferential analysis for pre and post urine specific gravity between trials is presented in Figure 15.

4.4.4 Urine Colour

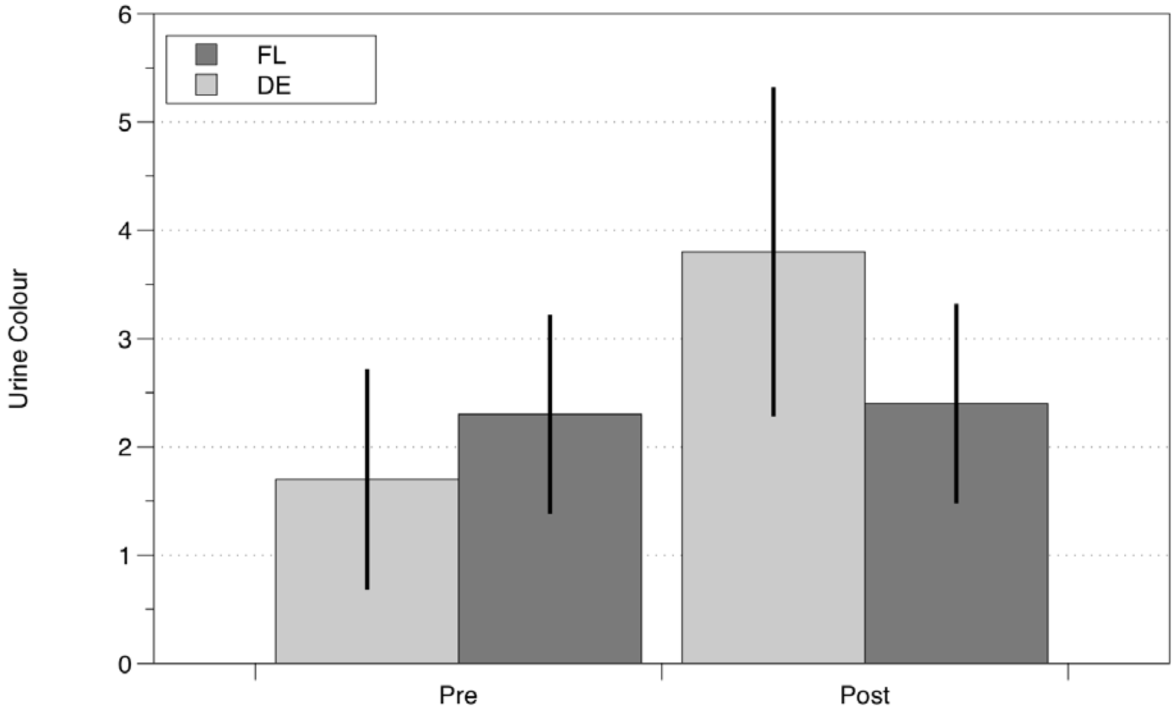

Figure 12. The mean (SD) pre and post urine colours for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid

Urine colour was 1.7 ± 1.0 vs 3.8 ± 1.5 when comparing pre vs post-test measures in the DE trial and there was a small change of 2.4 ± 0.9 vs 2.3 ± 0.9 in the FL trial when comparing pre vs post-test measures.

Figure 12 highlights that ad-libitum fluid supplementation maintained urine colour when comparing pre to post measures. Water intake, solely at half-time, led to an increase in urine colour in subjects when comparing pre to post. Inferential analysis for pre and post urine colour between trials is presented in Figure 15.

4.4.5 Haematocrit

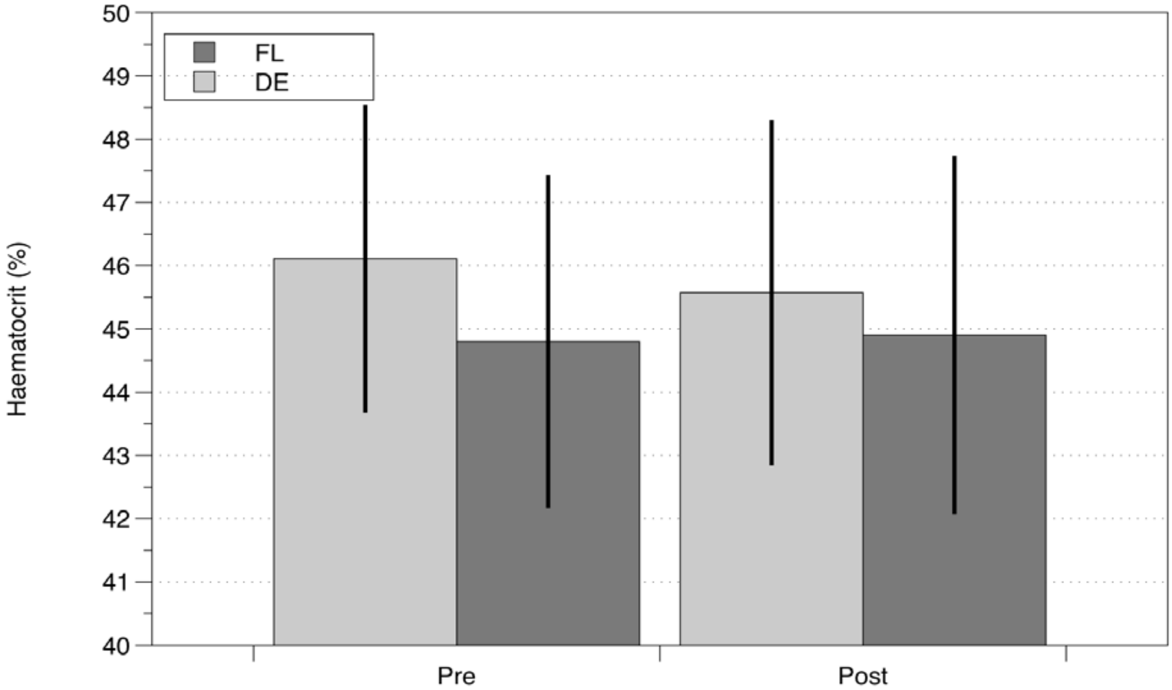

Figure 13. The pre and post mean (SD) haematocrit value for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid. Haematocrit changed little from 46.1 ± 2.4% vs 45.6 ± 2.7% when comparing pre vs post for DE and there was also minimal variation in hydration status with only a very small change from 44.8 ± 2.6% vs 44.9 ± 2.8% when comparing pre vs post haematocrit measures for FL respectively.

4.4.6 Plasma Volume change

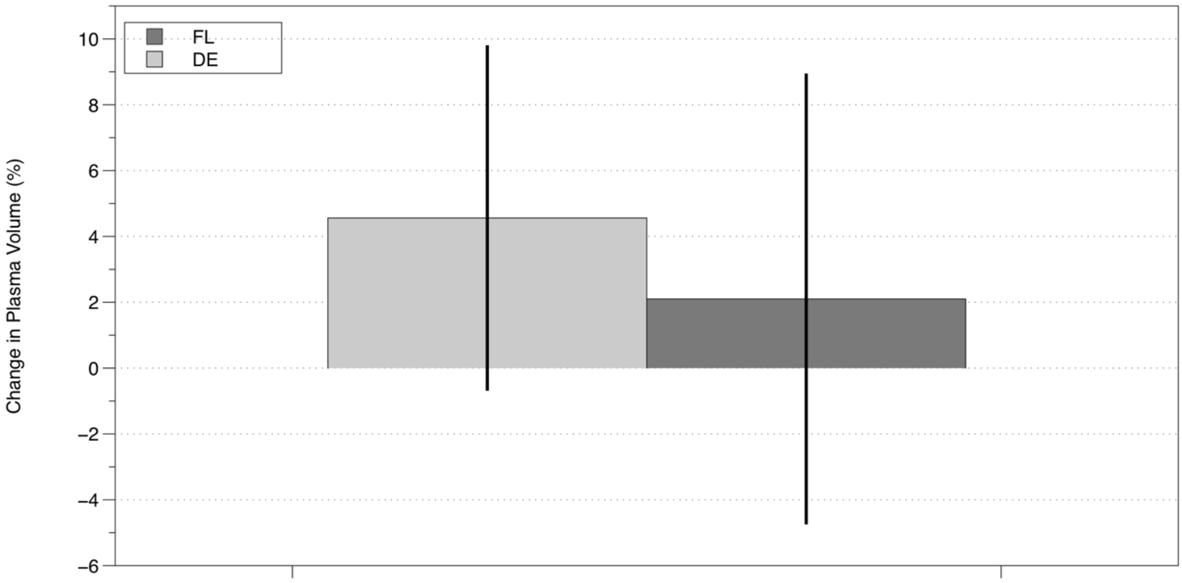

Figure 14. The mean (SD) plasma volume change for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid.

Plasma volume increased in both trials when comparing pre to post measurements, It increased more over the duration of the trial in the DE conditions compared to FL (4.6 ± 5.6% vs 2.1 ± 6.8%).

In relation to plasma volume, Figure 14 highlights that ad-libitum fluid supplementation through a PFDS maintained increased plasma volume from pre to post. However, there was a large expansion in plasma during the DE trial.

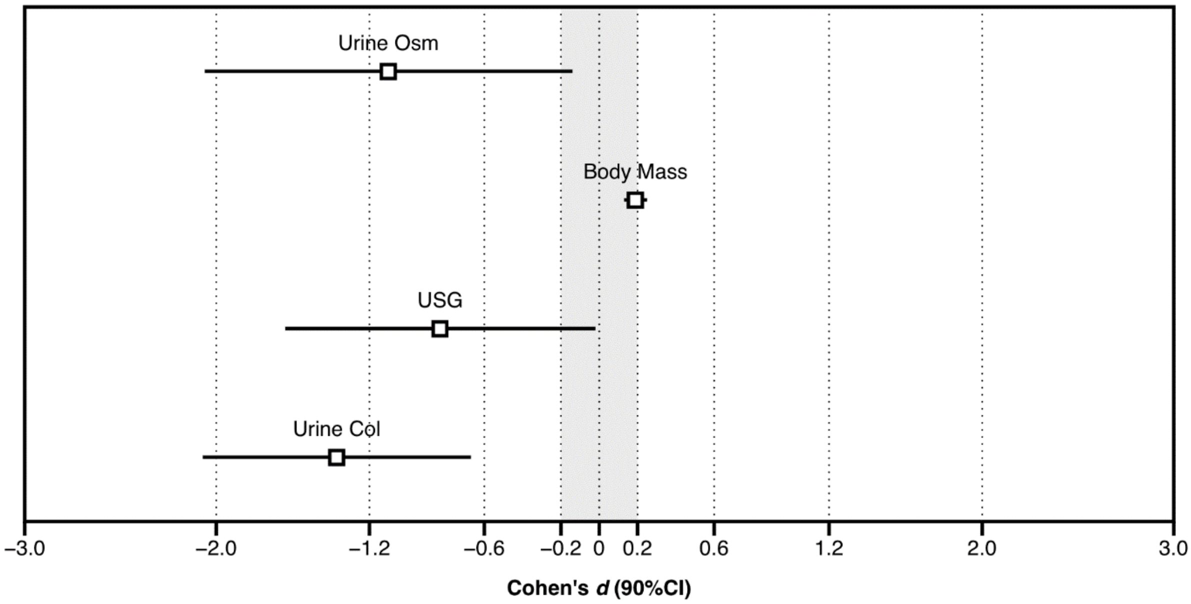

Figure 15. The mean difference as a Cohen's effect size (± 90% CI) for hydration markers between the dehydration and fluid trials. FL = Fluid trial, DE = Dehydration trial.

Regarding hydration markers, Figure 15 highlights that ad-libitum water supplementation improved hydration status in relation to urine osmolality and urine specific gravity (ES = -1.1 ± 0.96 & -0.83 ± 0.81), showing a moderate negative effect in favour of the FL trial. It also displays a large negative effect on urine colour in favour of the FL (ES = -1.37 ± 0.7) and a small positive effect on BM (ES = 0.19 ± 0.06).

4.5 Sweat Measures

4.5.1 Sweat Loss

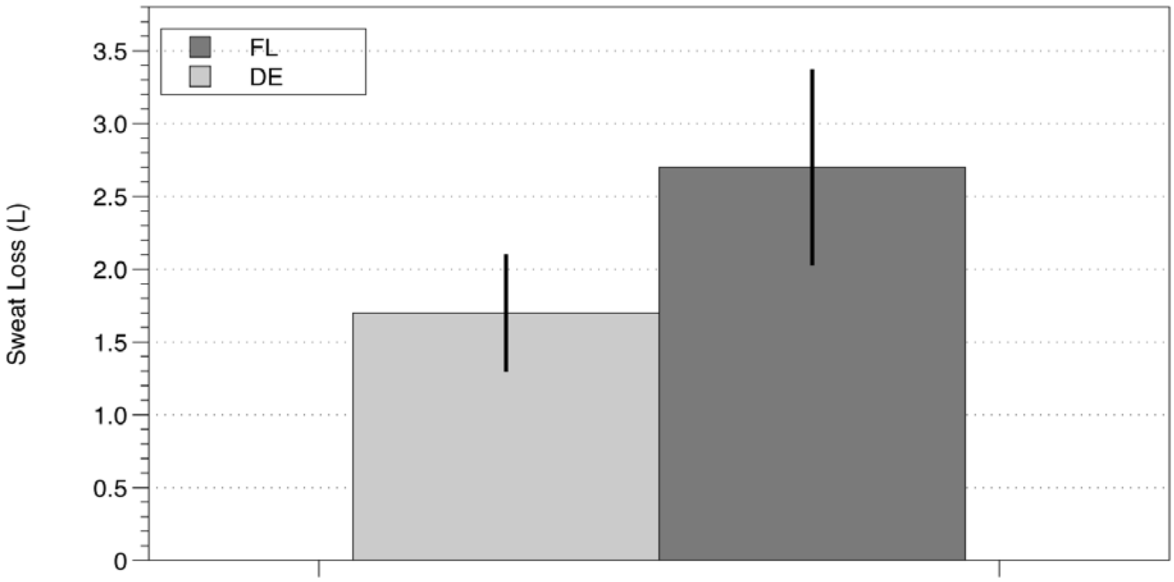

Figure 16. The mean (SD) sweat loss (L) for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid

There was a greater amount of sweat loss over the protocol in the FL trial compared to the DE trial. Participants lost 1.7 ± 0.4L in the DE trial vs 2.7 ± 0.7L in the FL trial respectively.

In relation to sweat loss, Figure 16 highlights that ad-libitum fluid supplementation increased sweat loss. Water intake, solely at half-time, led to a less sweat being lost in subjects. Inferential analysis for pre and post urine colour between trials is presented in Figure 18.

4.5.2 Sweat Rate

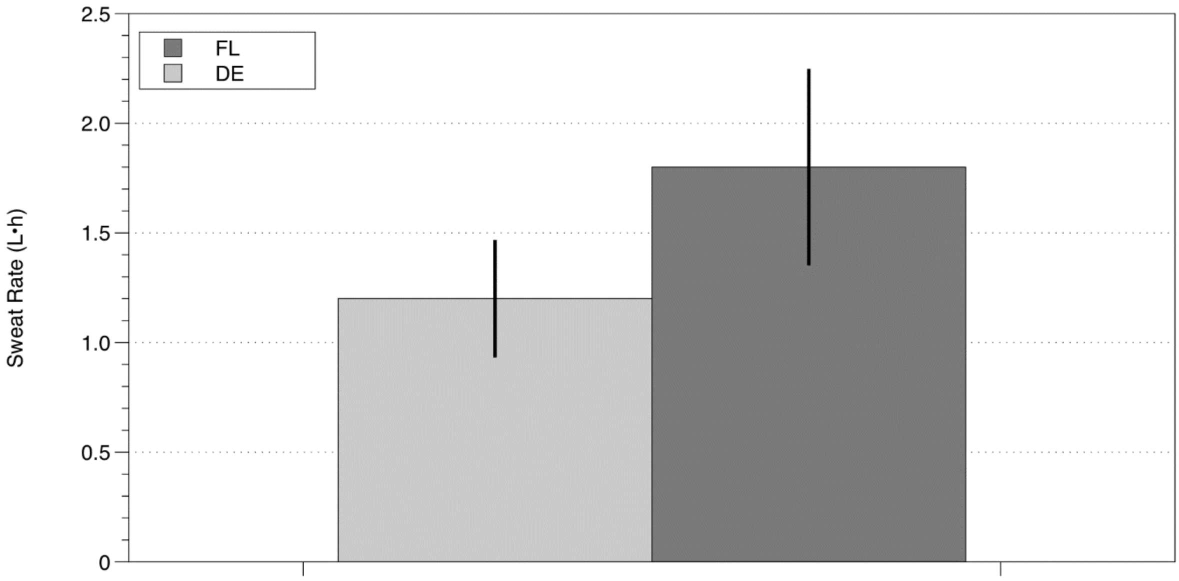

Figure 17. The mean (SD) sweat loss for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid

There was a greater rate of sweating over the protocol in the FL trial compared to the DE trial. Participants sweated at a rate of 1.2 ± 0.3L·h in the DE trial vs 1.8 ± 0.4L·h in the FL trial respectively. Figure 17 highlights that ad-libitum fluid supplementation increased the rate of sweating in subjects. Water intake, solely at half-time, led to sweat being lost at a reduced rate in subjects. Inferential analysis for pre and post urine colour between trials is presented in Figure 21.

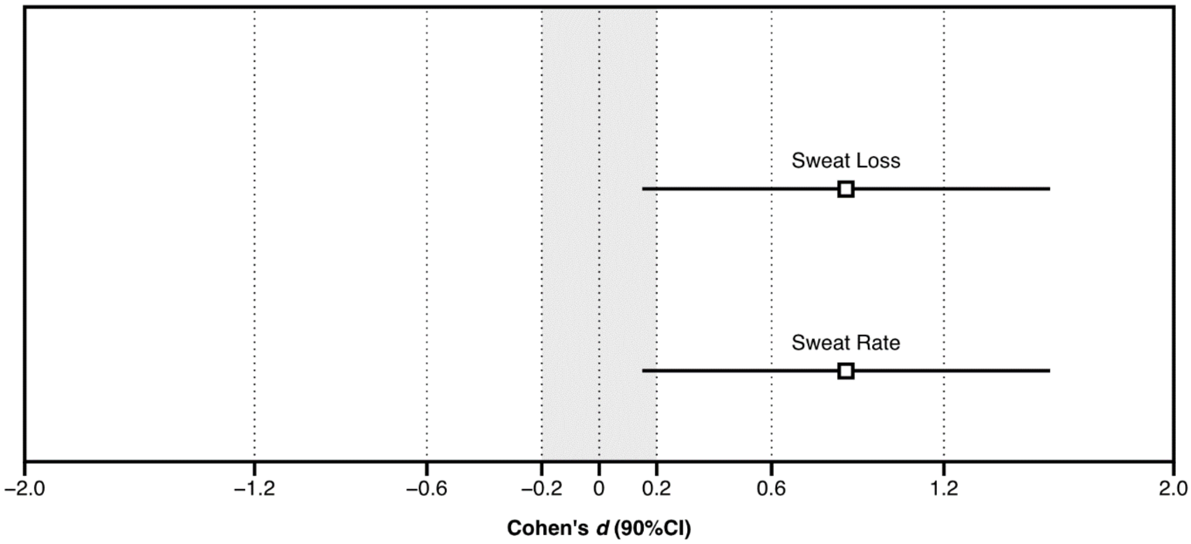

Figure 18. The mean difference as a Cohen's effect size (± 90% CI) for sweat rate and sweat loss between the dehydration and fluid trials. FL = Fluid trial, DE = Dehydration trial.

Regarding hydration markers, Figure 18 highlights that ad-libitum water supplementation had a moderate positive effect on sweat loss and sweat rate (ES = 0.86 ± 0.71 and 0.86 ± 0.71).

4.6 Subjective Measures

4.6.1 Rate of perceived exertion

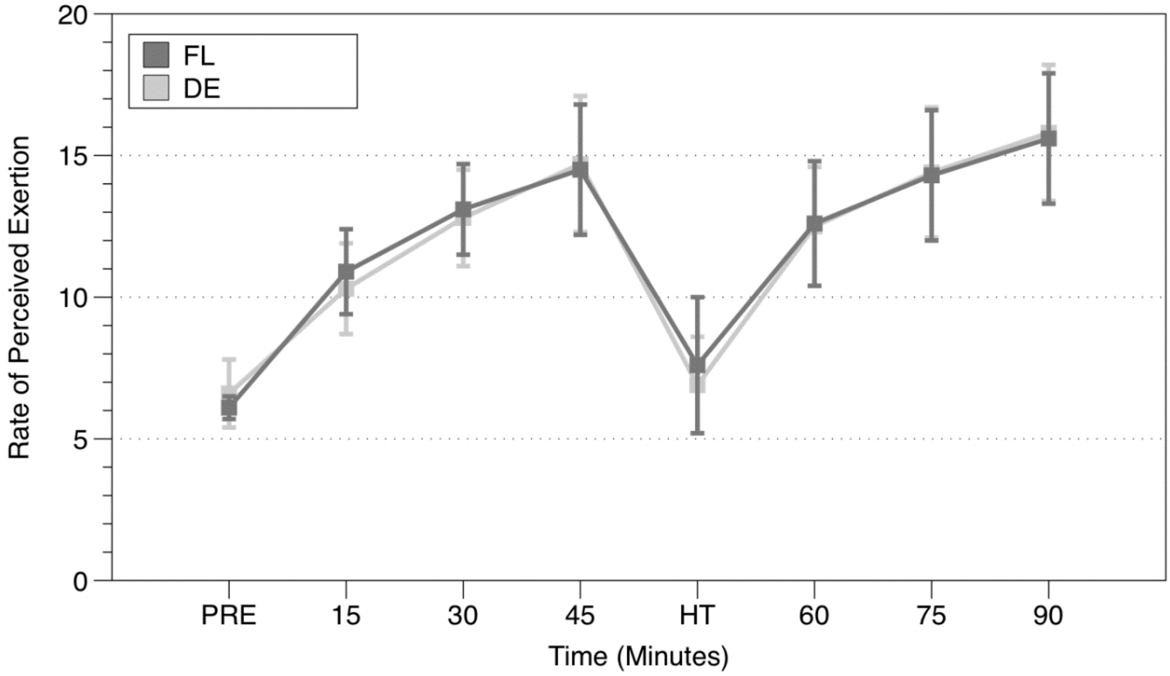

Figure 19. The mean (SD) rate of perceived exertion (RPE) before exercise began, and then at 15 minute intervals for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid. HT = End of Half time.

RPE was 12.6 ± 1.8 vs 12.8 ± 1.5 for DE versus FL in the 1st half and there was a very small change of 14.2 ± 2.1 vs 14.2 ± 2.2 for recorded RPE values when comparing DE versus FL trial in the 2nd half. Figure 19 highlights that the experimental conditions did not alter the subjects' perceived exertion when exercising. The biggest difference between the two trials occurred at the end of half time (DE = 6.9 ± 1.7 vs 7.64 ± 2.4). Inferential analysis for RPE between trials is presented in Figure 22.

4.6.2 Thermal Sensation

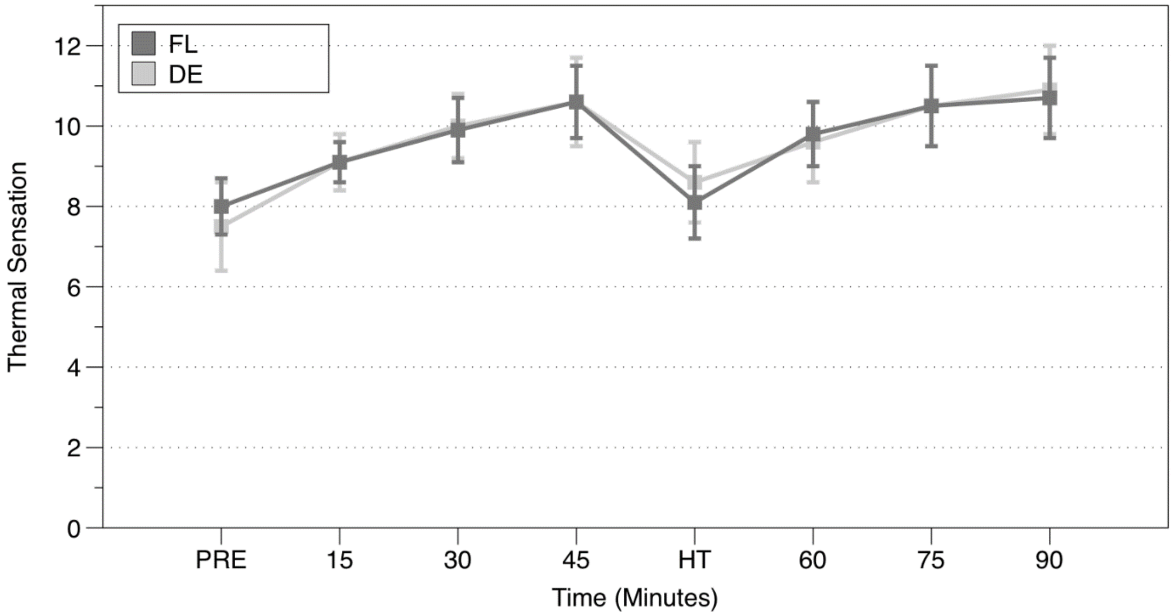

Figure 20. The mean (±SD) rate of thermal sensation (TS) before exercise began, and then at 15 minute intervals for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid. HT = End of Half time.

There was no change in TS (9.9 ± 0.8 vs 9.9 ± 0.6) for DE versus FL in the 1st half and there was no change of 10.3 ± 0.9 vs 10.3 ± 0.9 for recorded TS values when comparing DE versus FL trial in the 2nd half.

In relation to TS, Figure 20 highlights that the subjects' TS was slightly higher by the end of the DE trial versus the FL trial (10.9 ± 1.1 vs 10.7 ± 1) but values were similar at each interval in both trials. The biggest difference occurred at the end of half time (8.6 ± 1 in DE trial vs 8.1 ± 0.9 in the FL trial). Inferential analysis for TS between trials is presented in Figure 22.

4.6.3 Thermal Comfort

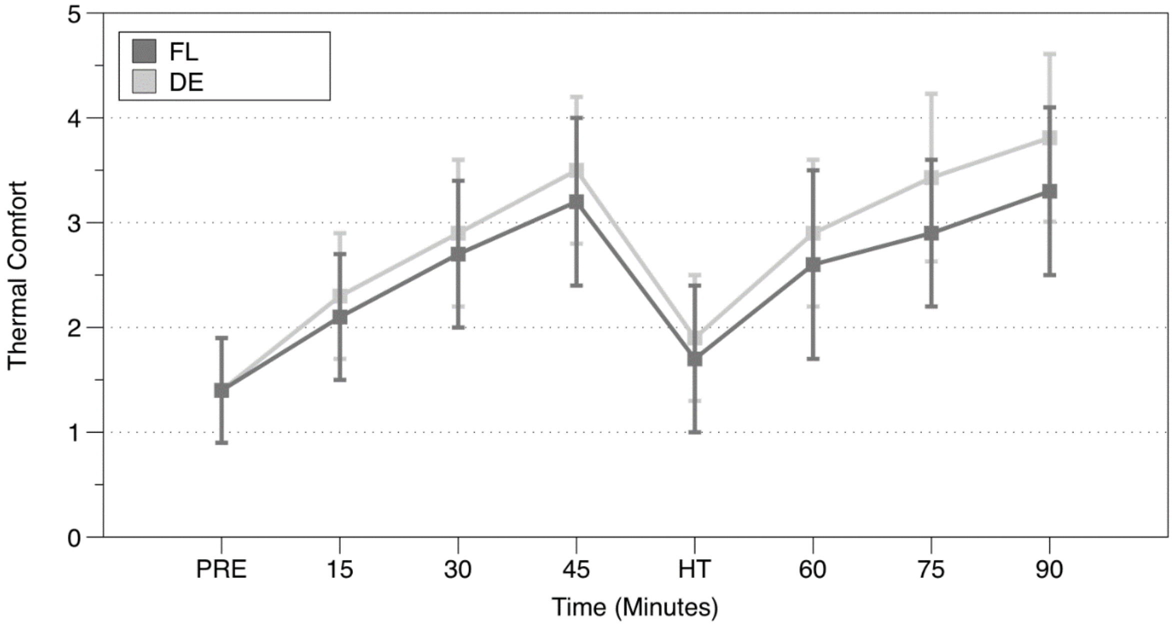

Figure 21. The mean (SD) rate of thermal comfort (TC) before exercise began, and then at 15 minute intervals for both the dehydration and fluid trials. DE = Dehydration, FL = Fluid. HT = End of Half time.

TC was higher in the DE trial versus the FL trial in the 1st half (2.9 ± 0.6 vs 2.7 ± 0.6) and was also higher in the 2nd half of the DE trial (3.38 ± 0.7 vs 2.9 ± 0.8).

In relation to TC, Figure 21 highlights that the subjects' thermal comfort was higher throughout the full DE trial. TC values increased gradually in both halves before dropping at the half-time break. The biggest difference occurred at the 75th minute (3.64 ± 0.9 vs 3 ± 0.7). Inferential analysis for TC between trials is presented in Figure 22.

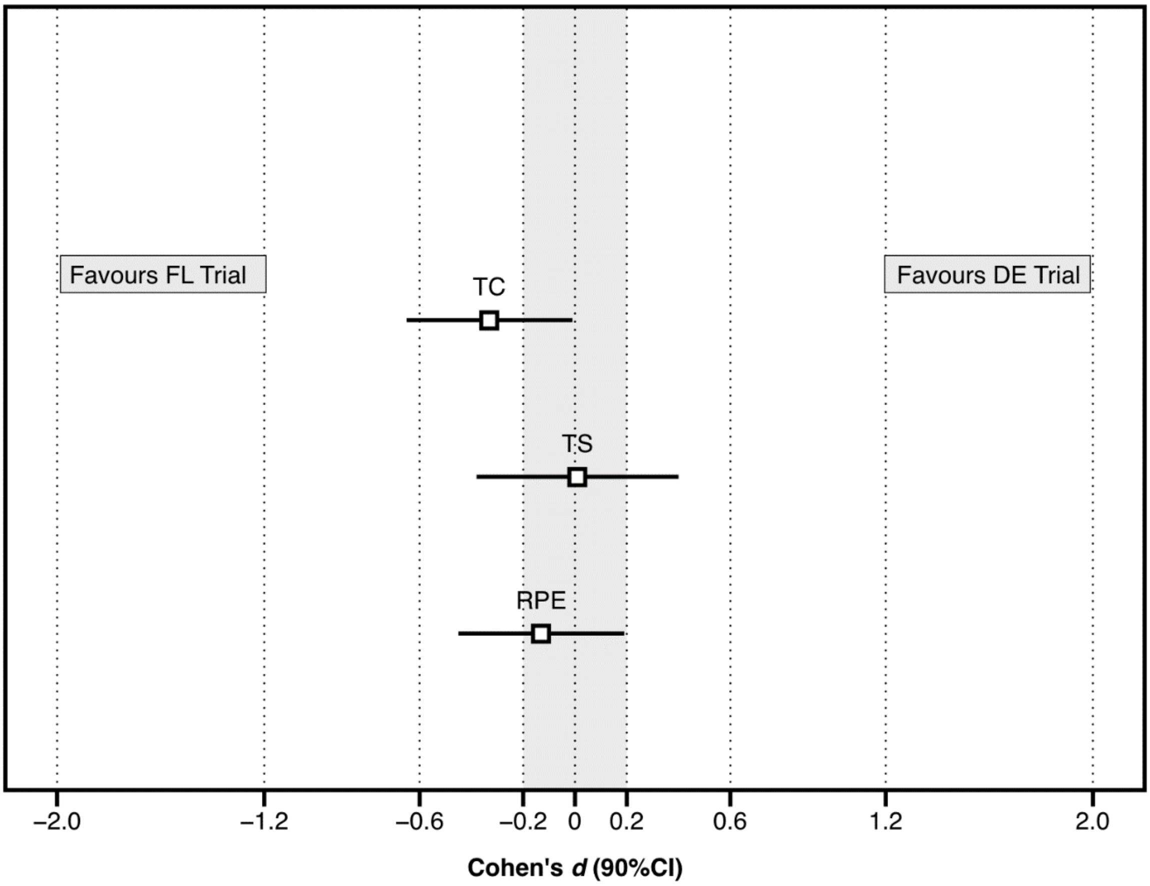

Figure 22. The mean difference as a Cohen's effect size (± 90% CI) for subjective measures between the dehydration and fluid trials. FL = Fluid trial, DE = Dehydration trial.

Regarding subjective measures, Figure 22 highlights that ad-libitum water supplementation improves thermal comfort with inferential analysis displaying a small negative effect upon thermal comfort ratings in favour of the FL trial (ES = -0.33 ± 0.32). It also displays that ad-libitum water supplementation has no effect on rate of perceived exertion and thermal sensation (-0.13 ± 0.32 & 0.01 ± 0.39).

Chapter 5

Discussion

5.1 Effect of a personal fluid delivery system on hydration status

5.1.1 Fluid intake quantity:

It was hypothesised that fluid intake would increase when subjects exercised in a thermal environmental while wearing the personal fluid delivery system (PFDS). In the present study, ad-libitum water supplementation resulted in an increase in the volume of fluid consumed by subjects. Subjects were restricted to only drinking 0.3 L of water at the half-time interval in the DE trial with no water being taken in either half. Understandably, the very large effect size between trials heavily favoured the FL trial as the subjects were permitted to consume up to 1.2 L in each half, as well as the compulsory 0.3 L at half-time. Therefore, the total potential volume of liquid that could be consumed during the whole duration of the FL trial was far higher than in the DE trial (2.7 L vs 0.3 L), due to the ability to carry fluid in the PFDS. It can be suggested that the increased availability of fluid during match play increases the quantity of voluntary fluid taken on board by referees during exercise. In relation to fluid intake quantity, this observation is comparable with Nolte, Noakes, and Nolte (2013), where soldiers under an ad-libitum drinking strategy consumed a total of 0.9 L more than a group restricted to 0.3 $L \cdot h^{-1}$ over 4 hours of marching. Despite fluid intake increasing in the ad-libitum group in Nolte and colleague's investigation, there was no alteration in hydration status between groups, which contradict hydration guidelines, stating that fluid should be made available to athletes in order to offset the reduction in performance through dehydration, which is accelerated in hot conditions (Burke, 2007). Arnaoutis et al. (2013) investigated pre-match hydration status and the effect of ad-libitum drinking on reducing dehydration in young soccer players. Results showed that the players, who had started training in a hypohydrated state, failed to ingest enough fluid to positively alter hydration status. An ad-libitum drinking strategy has previously been shown to increase fluid intake in hypohydrated subjects, when compared with a euhydrated group (Armstrong et al., 1997). This is consistent with Sawka, Montain, and Latzka (2001) findings that the stimulus to drink is only engaged after athletes are dehydrated (2%

BM loss). In the present study, athletes began the trial in either a euhydrated or hyperhydrated state, therefore, it could be suggested that the willingness to ingest the fluid available was due to the subject's knowledge of the benefits of hydration in hot conditions. It has previously been documented in relevant literature that education on the risks of dehydration under prolonged thermal stress, can lead to an increase in fluid intake (Brake & Bates, 2003). Therefore, it is necessary for referees to be correctly informed so that the implementation of an ad-libitum fluid supplementation strategy is exploited.

5.1.2 Body Mass

A decreased BM has been observed in several studies across various sports when exercising in both thermal and thermoneutral environments. In the present study, ad-libitum water supplementation had a possible small effect on BM loss (ES = 0.19 ± 0.06). When fluid intake was voluntary, BM was maintained; conversely, when athletes' fluid intake was restricted, there was a loss in BM. The results corroborate with the recommendations by Casa et al., (2000) where adequate fluid intake is said to increase previously lost BM through exercise and/or heat induced sweating.

Athletes performing prolonged exercise in hot conditions experience a total body water content decrease and consequently a reduction in BM. There is research supporting the claim that dehydrated individuals experience a decreased sweating rate (Sawka et al., 2007). This backs up the findings in the present study, where sweating rate was higher in subjects during the ad-libitum water supplementation trial. Ad-libitum fluid supplementation had a large positive effect on sweat loss throughout the trial, and subsequently sweat rate (ES = 0.86 ± 0.71). Investigators have reported increased sweating rates in hyperhydrated individuals during exercise (Lyons, Riedesel, Meuli, & Chick, 1990; Moroff & Bass, 1965), although there has also been contrasting evidence (Latzka et al., 1997, 1998; Ross et al., 2012). It is possible that the increased fluid intake in the FL trial amplified sweating rate due to an increased cutaneous vascular response. Furthermore, it has previously been reported that dehydration leads to an increase in cutaneous resistance (Gonzalez-Alonso et al., 1995) and that fluid ingestion increases cutaneous blood flow, regardless of plasma volume change (Montain & Coyle, 1992). These findings highlight the feasibility that maintaining a euhydrated state leads to an increased sweating rate, but also that an increased sweat rate through increased fluid intake is a thermoregulatory change, rather than a cardiovascular one. In future research, it would be worth investigating the effects of fluid intake strategies on sweat rates in either half. In the present study, it was not possible to compare sweat rates in both halves because half-time BM was not measured. Although not imperially measured, it is acknowledged that the subjects would have had to endure an increased metabolic cost due to the additional 1.2L of fluid added to the load at the start of the both halves. It is reported that an increased load whilst walking or running demands a higher oxygen cost (Ruckstuhl et al., 2010). When considering this, the increased weight carried could have caused a decline in performance, particularly in the 2nd half of the simulation.

5.1.3 Hydration markers

Urine Osmolality

As predicted, U_{Osm} increased from pre to post in the DE trial (U_{Osm} 117.1 ± 88.8 vs 308.2 ± 143.2). This phenomenon was likely caused by a decrease in the comparably low fluid intake in the DE trial (0.3 vs 1.9 L ± 1.54). It is worth noting that despite subjects in DE and FL trials beginning in a euhydrated state, subjects in the FL trial began the trial in a more hydrated state than the DE trial (U_{Osm} 117 ± 88.8 vs 315.8 ± 210.9). The higher pre-test measurement of U_{Osm} showed that the subjects in the FL trial were not as hydrated, could explain why body temperatures were similar between both trials. A lower U_{Osm} in the DE trial could have resulted in slower rate of increase in T_{rec}. Some investigators have reported lower T_{rec} during exercise when subjects are hyperhydrated (Grucza, Szczypaczewska, & Kozłowski, 1987). It may be necessary in future testing to ensure that subjects begin the trial similarly euhydrated. Comparably to U_{Osm}, results highlighted a clear effect in U_{SG} favouring the FL trial. Pre-post crossover inferential analysis displayed a moderate negative effect size (-0.84 ± 0.81) showing that there was a noteworthy decrease in subject's U_{SG} when under the FL trial conditions. It is no surprise that a relative increase in fluid intake will lead to a decrease in urine concentration. These results show that U_{SG} and U_{Osm} increase alongside a decrease in hydration status which is supported by findings from Popowski et al. (2001) who investigated how changes in hydration status affect urinary measures. The results observed in hydration status through U_{SG} and U_{Osm} are supported by the recorded urine colour in the present study. It is widely accepted that a darker colour indicates an increased concentration and a negative shift in hydration status. In the present study, ad-libitum water supplementation, carried out in the FL trial, had an effect on the change in pre to post comparisons of urine colour. From analysis of all urinary indices measured, it can be stated that the constant availability of fluid lead to subjects being able to maintain hydration status.

5.1.4 Plasma Volume

Blood plasma has been shown to expand through the increase of fluid intake. However, in the present study, % change in PV increased twice as much in the DE trial compared to the FL trial. It could be suggested that plasma volume increase was limited by the end of the FL trial due to a possible onset of hypovolemia. Vrijens and Rehrer (1999) observed a decrease in plasma sodium concentration when subjects ingested a sodium free fluid during exercise in heat. The combination of beginning the trial euhydrated, sodium loss through excess sweating and a sodium free rehydration strategy could have led to the reported smaller expansion in blood volume. It is proposed that a different rehydration strategy involving either a sodium or glycerol concentrated beverage be used for future investigations due to the necessity to replace sodium lost through sweating when exercising in hot conditions.

5.2 Effect of fluid intake on performance

There was no reported change in HR between the two conditions which shows the impact fluid pre-hydration strategies can play. Gonzalez-Alonso, Mora-Rodríguez, Below, and Coyle (1997) reported a decrease in of 7-8% in SV in athletes who were dehydrated and exercise in hot conditions (35ºC). Decreased SV is associated with an increase in HR, which was not observed between the two conditions. In the present study, it is likely that subjects' maintaining a euhydrated state throughout both trials, mitigated the adverse responses usually associated with thermoregulatory strain. It would be expected that if all subjects had attended both trials in a euhydrated state (300-700 mOsm•kg^{-1}), dehydration would have eventually occurred, leading to a CV drift, decreasing cardiac output and consequently a higher rate of increase in HR. In relation to performance on the exercise bike, there was no between trial effect observed in PPO. However, when observing PPO in the last 15 minutes (final three sprints) there was a small positive effect favouring the FL trial (ES = 0.13 ± 0.37). This highlights the importance of fluid intake in the final periods of match play. It is understood that in soccer, players experience the most fatigue in the latter stages of the match (Mohr, Krustrup, & Bangsbo, 2005). Additionally, there is evidence that most goals are scored either in the last 30 minutes (Yiannis, 2014) or in the last 15 minutes of a match (Abt, Dickson, & Mummery, 2002) due to the onset of fatigue and reduced concentration levels (Njororai, 2013; Reilly & Korkusuz, 2008). Maintaining a euhydrated state from start to finish can possibly delay fatigue of the skeletal muscles. These results contradict findings from research by (Gonzalez-Alonso et al., 1999), where increased muscle temperature was related to an increase in fatigue. The lack of effect the FL trial had on power output could further be explain if one looks at findings by Jones, Cleary, Lopez, Zuri, and Lopez (2008). These researchers discovered that dehydration causes a decline in lower limb anaerobic muscular power in a hot and humid environment. This suggests that if the subjects in the present study had been exposed to the environment for longer, or perhaps had been exercising in a hotter ambient temperature, there would have been a positive effect on PPO in the FL trial.

5.3 Effect of fluid intake on subjective measures

In relation to thermal sensation, the FL trial had no effect (ES = 0.01± 0.39) on how hot the subjects felt whilst exercising. It was hypothesised that ad-libitum fluid supplementation would give the subjects the belief that they were not as hot due to possible physiological changes. However, the subjects' thermal sensation levels had already reached 10 (hot) by the 20th minute in both trials. It is possible that subjects felt hotter in the trial temperature because they were unacclimated to the conditions of the environmental chamber. Despite being physiologically capable of completing the trial with minimal cardiovascular strain, they felt hot with and without fluid intake. Thermal comfort denotes how comfortable or satisfied the subject is with their perceived body temperature. Thermal comfort levels were influenced by the implementation of an ad-libitum fluid strategy (ES = -0.33 ± 0.32). It is likely that, despite mean thermal sensation levels being high ($\geq$ 10) through the majority of the trial, the subjects felt more capable or comfortable completing the trial when they had sufficient fluid available.

This placebo effect would have led to an increase in satisfaction with the temperature of their body despite both having very similar physiological outcomes (HR, T_{rec}, MST).

5.4 Effect of fluid intake on thermoregulatory changes

5.4.1 Core temperature

There was a linear increase in all recorded body temperatures from start to the end of exercise, with a drop at the end of the half-time interval when participants were not exercising and had rehydrated. No difference was observed in the rate of T_{rec} elevation between the two trials. As previously mentioned, hydration status has a key influence on T_{rec} during heat stress in humans. Sub-maximal exercise can lead to T_{rec} increases after 40 minutes when fluid is restricted (Marino, Kay, & Serwach, 2004). With this in mind, it could be suggested that in the DE trial, the half-time interval was at almost optimal time, as it provided subjects with 0.3 L of cold water. This rehydration period would have contributed to the reduction of T_{rec} and subsequently attenuated any further thermoregulatory strain, allowing adequate recovery. It is worth mentioning that, despite T_{rec} not being affected by the increased fluid intake, T_{rec} still reached 39ºC by the end of both trials. This shows the risks placed upon uncclimatised players and referees when performing for prolonged periods in hot conditions.

5.4.2 Skin temperature

Inferential analysis on the FL trials effect on MST resulted in possibly a small negative effect. These results show that there is a slight shift in MST when the body's fluid intake is maintained throughout exercise. It could be argued that this effect was limited by the fact the environmental conditions were not hot enough. It has been previously reported that when ambient temperatures exceed 36ºC, athletes experience an increase thermoregulatory load (Wendt et al., 2007), causing an increase in T_{sk} when fluid requirements are not met. With regards to individual T_{sk} (chest, bicep, thigh and calf), ad-libitum water supplementation in the FL trial only had an effect on subjects' T_c. There is no clear reason to suggest why this outcome occurred, however, one possible suggestion could be related to clothing insulation; there may have been a restriction in sweat evaporation in chest, bicep and thigh due to wet clothing sticking to the skin. This means that there would have been a decreased effectiveness in heat dissipation through sweat loss, which is key in reducing T_{sk}. With the calf being the only skin landmark that wasn't covered by clothing, the increased fluid intake could have influenced the sweat rate and subsequently allowed cooling to occur.

5.5 Limitations

During the present study, there were a number of limitations. The first limitation is that there were no initial control tests in a thermoneutral environment for each condition. Without measuring the effects of a PFDS on fluid intake in a thermoneutral environment, there is no possibility to compare and understand how much more fluid the subjects consumed in comparison to normal conditions. Furthermore, there was no opportunity to assess the magnitude of change in subjects' performance levels and physiological responses when there is no baseline value.

The second limitation relates to the duration and selected temperature of the trial. Piloting the DE trial at 30ºC elicited the physiological responses that had been previously observed in relevant literature, however the FL showed no real effect on physiological and thermoregulatory responses. It can be suggested that despite the protocol being a soccer specific simulation, the duration was not long enough to produce a noteworthy decline in physiological performance in either trial. As argued in the discussion, subjects attending the trial in a hyperhydrated condition, along with a compulsory 0.3 L at the half time interval, is likely to have removed the onset of dehydration within the full 105 minute trial. Furthermore, with the duration of the trial being somewhat inflexible due to it being a soccer specific simulation, the temperature of the trial was a variable that would stimulate specific thermoregulatory responses in subjects. An increased temperature of $\geq$36ºC could have possibly led to fluid intake having a larger effect on the measured physiological variables.

Another limitation relates to the data collection phase. As mentioned previously in the discussion, PFDS was refilled at half-time with another 1.2L of water. The extra 1.2kg load was not considered during the procedure and may have contributed to a decline in performance in both halves.

A further limitation was the sample size. Testing yielded a total of 14 subjects fully completing the testing process. Only having 14 participants was a limiting factor because it reduced the power to detect differences in the means of the two conditions. It was hoped that 20 participants could have provided the full required data set, however it proved difficult to recruit participants and have fully completed trials due to the difficulty and length of the protocol.

Another limitation was the simulation protocol and the inability to conduct a true soccer simulation. Despite the multiple activity changes in speed and duration to represent forward running activity changes, the fact that the subjects are unable to mimic specific footballing movements, experienced by referees, is a limitation. Movements including, but not limited to, sideways running, turning and backwards movement, which are commonly observed in every soccer match and are essential for a true soccer simulation. Furthermore, it is understood that these specific movements can increase the physiological demands during exercise. Another limitation is in relation to the time-related activity profiles. It has been observed in literature that soccer players and referees' physical performances decline towards the latter stages of match play. The treadmill protocol in the present study's simulation does not allow for a reduction in distance covered or running intensity when subjects are exercising on the treadmill. The only self-paced activity which could display a decline in performance is during the six second cycle sprint; this itself is another limitation as the difference in modality does not mimic that of a soccer match which is carried out by players and referees exclusively in some form of running capacity. This is a key limitation as it doesn't replicate the exact responses that are experienced by the athletes.

Chapter 6

Conclusion

In conclusion, the present study presents evidence that wearing a personal fluid delivery system while performing in hot conditions greatly increases fluid intake and has a small positive effect on thermal comfort. The extremely large effect on fluid intake highlights that fluid available during match play in a hot and humid environment could increase greatly if fluid was made constantly available. This strategy presents further indication that the increase in fluid intake has a positive influence on hydration status, however, it also displays evidence that drinking fluid solely at half-time is by no means a poor hydration strategy when referees are euhydrated or hyperhydrated prior to performance. Hydrating adequately before match play is shown to be enough to delay the onset of dehydration throughout the trial. Therefore, it is uncertain if this increase in fluid intake will reduce the thermoregulatory strain on referees due to the pre-exercise hydration status of the subjects. It would be necessary to measure these variables in the same conditions, but with participants being either hypohydrated or euhydrated before exercise to gain a clear effect. It is also unclear if the increased fluid intake associated with fluid availability can attenuate a physiological or performance decline. From the findings of this study, it can be recommended that more research be carried out on the effects of heat stress on soccer referees along with optimal hydration strategies to reduce the effects of dehydration in a thermal environment, especially in the 2nd half of the match. A similar investigation carried out on a female cohort would also be beneficial due to the lack of research carried out on female footballers or referees in the heat. Additionally, it would be interesting for research to be carried out on referees of a varied age group to investigate how age effects the performance of a referee in extreme environmental conditions and also through different fluid intake strategies.

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Appendices

Appendices A:

Department of Sport, Health & Exercise Science UNIVERSITY OF Hull

Informed Consent Declaration

Project title	The effect of a personal fluid delivery system on fluid intake, thermoregulation, and physical performance during a 90 minute soccer simulation.
Principal investigator	Name: Dr Grant Abt Email address: G.Abt@hull.ac.uk Contact telephone number:
Student investigator (if applicable)	Name: Lewis Wombwell Email address: L.Wombwell@2011.hull.ac.uk Contact telephone number: 07717779530

Please Initial

I confirm that I have read and understood all the information provided in the Informed Consent Form (EC2) relating to the above project and I have had the opportunity to ask questions.

I understand this project is designed to further scientific knowledge and that all procedures have been risk assessed and approved by the Department of Sport, Health and Exercise Science Research Ethics Committee at the University of Hull. Any questions I have about my participation in this project have been answered to my satisfaction.

I fully understand my participation is voluntary and that I am free to withdraw from this project at any time and at any stage, without giving any reason. I have read and fully understand this consent form.

I agree to take part in this project.

....

Name of participant Date Signature

....

Person taking consent Date Signature

Appendices B:

Department of Sport, Health & Exercise Science

UNIVERSITY OF Hull

Pre-Exercise Medical Questionnaire

The information in this document will be treated as strictly confidential

Name: ....

Date of Birth: .... Age: .... Sex: ....

Blood pressure: .... Resting Heart Rate: ....

Height (cm): .... Weight (Kg): ....

Please answer the following questions by putting a circle round the appropriate response or filling in the blank.

1. How would you describe your present level of **exercise** activity?
   Sedentary / Moderately active / Active / Highly active

2. Please outline a typical weeks exercise activity

   ....
   ....
   ....

3. How would you describe your present level of **lifestyle** activity?
   Sedentary / Moderately active / Active / Highly active

4. What is your occupation? ....

5. How would you describe your present level of fitness?
   Unfit / Moderately fit / Trained / Highly trained

6. Smoking Habits Are you currently a smoker? Yes / No
   How many do you smoke .... per day
   Are you a previous smoker? Yes / No
   How long is it since you stopped? .... years
   How many did you smoke? .... per day

7. Do you drink alcohol? Yes / No

If you answered **Yes** and you are male do you drink more than 28 units a week? Yes / No

If you answered **Yes** and you are female do you drink more than 21 units a week? Yes / No

8. Have you had to consult your doctor within the last six months? Yes / No
If you answered **Yes**, Have you been advised **not** to exercise? Yes / No

9. Are you presently taking any form of medication? Yes / No
If you answered **Yes**, Have you been advised **not** to exercise? Yes / No

10. Do you have a history of fainting during or following exercise? Yes / No
If **Yes**, please provide details...
....
....

11. To the best of your knowledge do you, or have you ever, or have a family history:

a Diabetes? Yes / No   **b** Asthma? Yes / No
c Epilepsy? Yes / No   **d** Bronchitis? Yes / No
e ✸Any form of heart complaint? Yes / No   **f** Raynaud's Disease Yes / No
g ✸Marfan's Syndrome? Yes / No   **h** ✸Aneurysm / embolism? Yes / No
I Anaemia Yes / No

12. ✸Are you over 45, and with a history of heart disease in your family? Yes / No

13. Do you currently have any form of muscle or joint injury? Yes / No
If you answered **Yes**, please give details………………………………….
………………………………………………………………………………
……………………………………………………………………………. …..

14. Have you had to suspend your normal training in the last two weeks? Yes / No
If the answer is **Yes** please give details…………………………………………….
……………………………………………………………………………………….
……………………………………………………………………………………….
……………………………………………………………………………………….

15. ✸ Please read the following questions:
a) Are you suffering from any known serious infection? Yes / No
b) Have you had jaundice within the previous year? Yes / No
c) Have you ever had any form of hepatitis? Yes / No
d) Are you HIV antibody positive Yes / No
e) Have you had unprotected sexual intercourse with any person from an HIV high-risk population? Yes / No
f) Have you ever been involved in intravenous drug use? Yes / No
g) Are you haemophiliac? Yes / No

16. As far as you are aware, is there anything that might prevent you from successfully completing the tests that have been outlined to you? Yes / No.

IF THE ANSWER TO ANY OF THE ABOVE IS YES:

A) DISCUSS WITH THE TEST ADMINISTRATORS OR ANOTHER APPROPRIATE MEMBER OF THE DEPARTMENT.

B) QUESTIONS INDICATED BY (✶) ANSWERED YES: PLEASE OBTAIN WRITTEN APPROVAL FROM YOUR DOCTOR BEFORE TAKING PART IN THE TEST.

PLEASE SIGN AND DATE AS INDICATED ON THE NEXT PAGE

Participant Signature: ………………………………………… Date…………………

Test Administrator:……………………………………………… Date…………………

Supervising staff member……………………………………………… Date……………………

Parent (if minor)………………………………………………… Date: ………………

THIS SECTION IS ONLY REQUIRED FOR RETURN VISITS!

For any future testing sessions it is necessary to verify that the responses provided above are still valid, or to detail any new information. This is to ensure that you have had no new illness or injury that could unduly increase any risks from participation in the proposed physical exercise.

ANSWER THE FOLLOWING QUESTION AT EACH REPEAT VISIT.

Is the information you provided above still correct, and can you confirm that you have NOT experienced any new injury or illness which could influence your participation in this exercise session?

Repeat 1	Yes / No*	Signature:	Date:
*Additional info required:			
Repeat 2	Yes / No*	Signature:	Date:
*Additional info required:			
Repeat 3	Yes / No*	Signature:	Date:
*Additional info required:			
Repeat 4	Yes / No*	Signature:	Date:

*Additional info required:			
Repeat 5	Yes / No*	Signature:	Date:
*Additional info required:			

Appendices C:

Perceived exertion scale (Borg, 1973)

6	
7	**Very, very light**
8	
9	**Very light**
10	
11	**Fairly light**
12	
13	**Somewhat hard**
14	
15	**Hard**
16	
17	**Very hard**
18	
19	**Very, very hard**
20	

Thermal Sensation scale

1	**Unbearably cold**
2	**Extremely cold**
3	**Very cold**
4	**Cold**
5	**Cool**
6	**Slightly cool**
7	**Neutral**
8	**Slightly warm**
9	**Warm**
10	**Hot**
11	**Very hot**
12	**Extremely hot**
13	**Unbearably hot**

Thermal Comfort scale

1	**Very comfortable**
2	**Comfortable**
3	**Slightly comfortable**
4	**Uncomfortable**
5	**Extremely uncomfortable**